Application of Quality Improvement Techniques to the Powder Coat Process

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Abstract

An interdisciplinary senior design team at a private engineering school recently completed a project for a local industry client. Dr. Joan Burtner served as a technical advisor for the project that involved investigating ways to improve the powder-coat application process at a middle Georgia manufacturing facility. The industry client proposed the project as part of the facility's ongoing Six Sigma efforts. Following the DMAIC process, the team used process maps, cause and effect matrices, failure modes and effects analysis, and control charts to evaluate the process and recommend changes. Appropriate statistical techniques were used to analyze the data. The project's final deliverable was an industry-specific control plan.

Keywords: Quality, Six Sigma, Process Improvement

I. Introduction

An interdisciplinary senior design team recently completed a project for a local industry client. Dr. Joan Burtner served as a technical advisor for the project that involved investigating ways to improve the powder-coat application process at a middle Georgia manufacturing facility. The industry client proposed the project as part of the facility's ongoing Six Sigma efforts. Following the DMAIC process, the team used process maps, cause and effect matrices, failure modes and effects analysis, and control charts to evaluate the process and recommend changes.

II. Six Sigma

Six Sigma is a proven methodology for improving business processes by using statistical methods to identify and reduce process variation. Six Sigma has been described as "a comprehensive and flexible system for achieving, sustaining and maximizing business success. Six Sigma is uniquely driven by a close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes" [6, p. xi]

The Six Sigma philosophy popularized by Motorola in the early 1980s extended the quality tools that were part of the Total Quality Management movement by adding an emphasis on financial accountability [2]. The Six Sigma process was further refined and popularized by Jack Welch at GE in the late 80s and early 90s. Now in the year 2004, Six Sigma initiatives have been credited with increasing productivity and profitability at numerous companies in the business sector.

Although it evolved from the total quality movement, Six Sigma quality emphasizes economic value and practical utility. Harry and Schroeder [5, p6] define the new definition of quality as "a state in which value entitlement is realized for the customer and provider in every aspect of the business relationship."
Thus the translation of the Voice of the Customer into technical terms that describe what the customer wants is an important starting point for a Six Sigma project.

Implementation of Six Sigma involves a systems approach to problem solving and emphasizes the three C's: common metrics, constant communication, and culture change. Pande et al. [6] describe the potential benefits of the Six Sigma approach:

- Cost reduction
- Productivity improvement
- Market share growth
- Customer retention
- Cycle-time reduction
- Defect reduction
- Culture change
- Product/service development

III. Powder Coat Paint Cell Project

The powder coat paint cell project was conducted as part of Mercer's senior-level capstone design experience. The experience involves two semester-long courses that are required for graduation with a bachelor's degree in engineering or industrial management. Student teams typically consist of two or three senior-level students; many teams are interdisciplinary. The senior design course is taught by an engineering professor who is responsible for organizing the course and assigning grades. Student teams must find a suitable project and select a faculty member who will serve as a technical advisor for the project. Some students find projects within the School of Engineering and have an internal client; others find a project that is being sponsored by an external client. Once projects are approved, the instructor of the senior design course takes on the role of project manager for all of that year's senior design projects.

The first author served as the technical advisor for the quality component of the paint cell project that is the topic of this paper. The project was conducted by an interdisciplinary team that consisted of an industrial management and an industrial engineering student. The external client was a local Georgia manufacturer who is highly committed to the Six Sigma philosophy. As defined by the client, the project follows the classic Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) cycle with an emphasis on the Define-Measure-Analyze stages.

The powder coating process may involve two different application methods. In one method, the part is lowered into a fluidized bed of the powder, which is electrostatically charged. In the other method, which was used in this study, the powdered paint is electrostatically charged and sprayed onto the part.

Figure 1. A Typical Spray Paint Booth

Various factors contribute to the success or failure of the powder coating operation. Pre-treating is essential for adequate adhesion. The work environment must be kept clean to avoid contamination. Making the proper transition between paint colors is crucial. The efficiency and reliability of the operators are important factors. However, according to Jensen, proper training of operators may be the key factor. Figure 1 shows a typical spray paint booth, courtesy www.thefabricator.com (Accessed March 12, 2004)

One of the first steps in understanding and improving a process is to develop a simple process map for the paint cell. As can be seen in Figure 2, the basic process steps are Load Wash Dry Paint Cure. After curing, the products that pass inspection go to unload; the other items go to rework or the scrap bin.

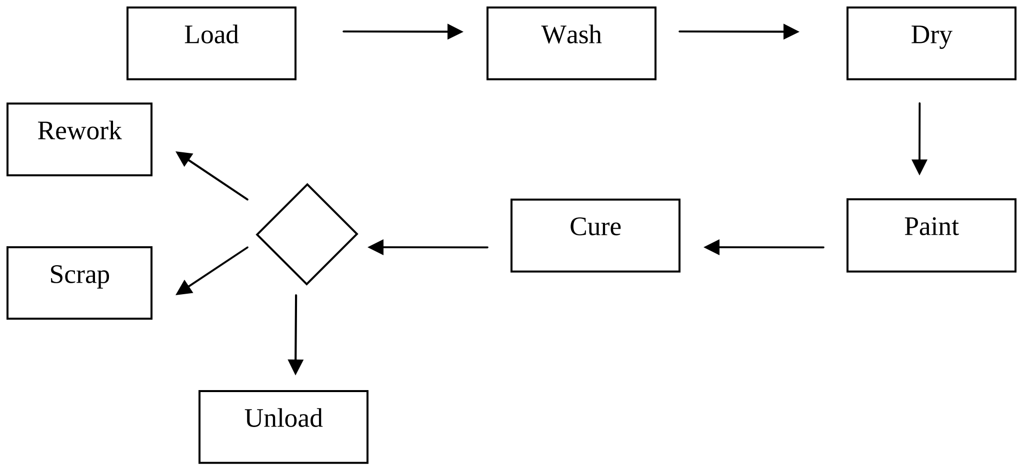

Figure 2. Paint Cell Process Steps Map

The Voice of the Customer is an essential component of the Six Sigma process. An earlier Six Sigma team at the manufacturing facility had investigated customer needs with respect to the powder coating process. It was determined that there were three factors most important to the customer. These factors were: 1)Minimal paint thickness, 2)Even coverage, and 3)Scratch-free parts. As Fowlkes [3] shows, factors related to ensuring quality in the paint spray finishing process may be modeled as follows.

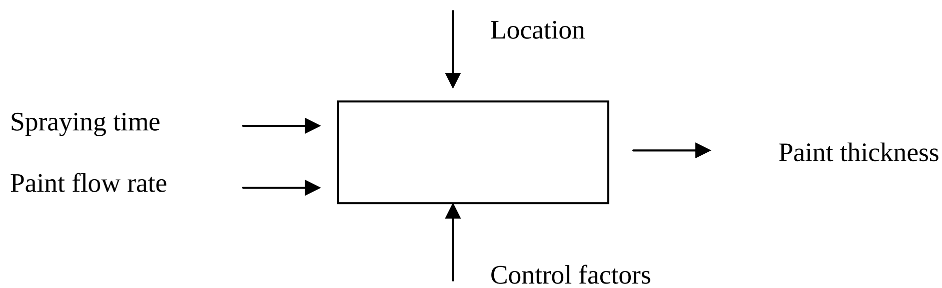

Figure 3. Paint Thickness Control Input Output Map

Once the team had modeled the process, they worked on developing a Cause and Effects Matrix based on the customers' three most important factors. The factors relative weightings were estimated as follows: paint thickness-7, even coverage-9, and damage free-10. Correlation values were limited to 0,1,3 or 9 as suggested by George [4]. Typical results from the Cause and Effects Matrix are shown in Table 1. By rank ordering the calculated value for each process input, the team was able to determine the most critical components with respect to the Voice of the Customer.

Table 1. Cause and Effects Matrix - Typical Results

#	Process Step	Process Input	Customer Importance Value			Total
			Paint Thickness	Even Coverage	Damage Free	
			7	*9*	*10*	
1	Load	Hook	3*	3	3	78**
2	Load	Conveyor	3	3	3	78
3	Paint	Spray Gun	9	9	1	154
4	Cure	Temperature	3	3	1	58

Correlation values 0, 1, 3, 9 **Sample calculation 7*3+9*3+10*3=78

The preliminary data collection plan involved a student team consisting of an Observer and a Recorder. Random sampling plan was devised and data collection began. The goal was to collect 75 observations for the baseline control charts. The collection sheet variables were determined by the client on the basis of a previous Six Sigma project. The following week, at a meeting with the technical advisor, the data were reviewed. The team members felt that the data collection form, and the method itself, needed revision. As a result, the students enlisted the help of a third team member. The new roles were Observer (voltage, temperature, etc), Thickness Gauge Operator, and Thickness Gauge Recorder. The team felt that the cells in the data collection form provided by the company were too small, and new forms were designed. After talking with their client, the team decided to limit the variables to the most important components– panel, color, hook, 5 locations. They used larger cells for recording data. This method proved viable, and the data collection plan proceeded.

Using the paint thickness as a factor, the team identified five locations (Figure 4) and conducted repeated measures to collect data for the baseline chart.

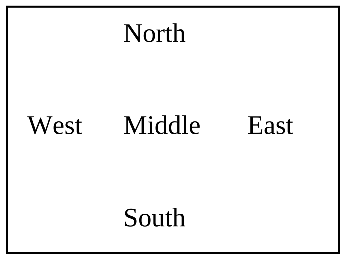

Figure 4. Typical Location Variables

The preliminary R and Xbar control charts for one location are shown in Figure 5.

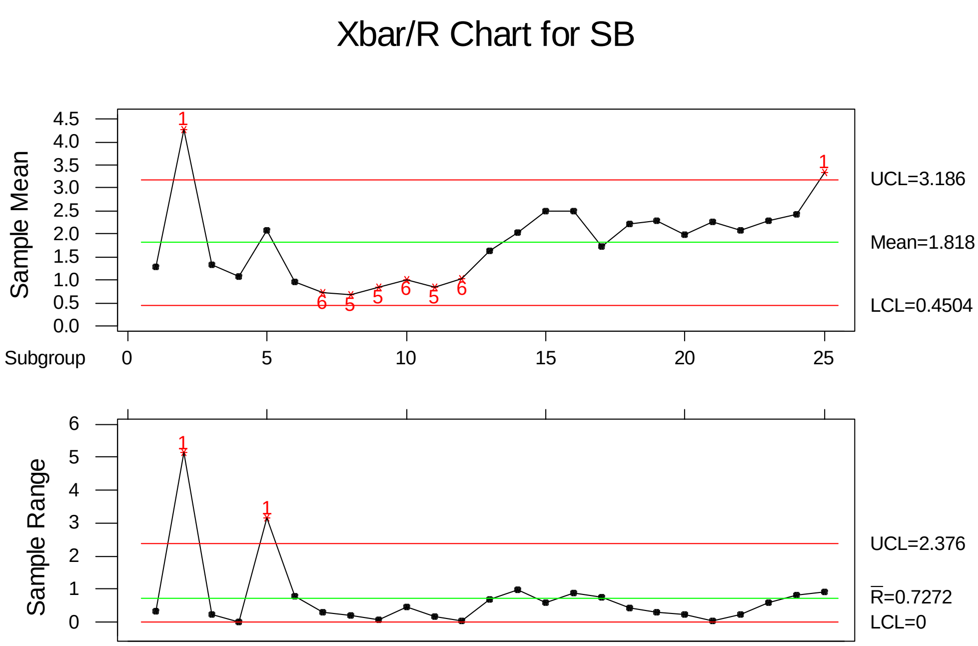

Figure 5. Preliminary Baseline Control Charts (Typical)

Using guidelines listed in Besterfield, et al. [1], it was determined that the range was out of control at points 2 and 5. Assuming special causes (in this case human error in data recording) these two samples were eliminated. The revised control charts are shown in Figure 6.

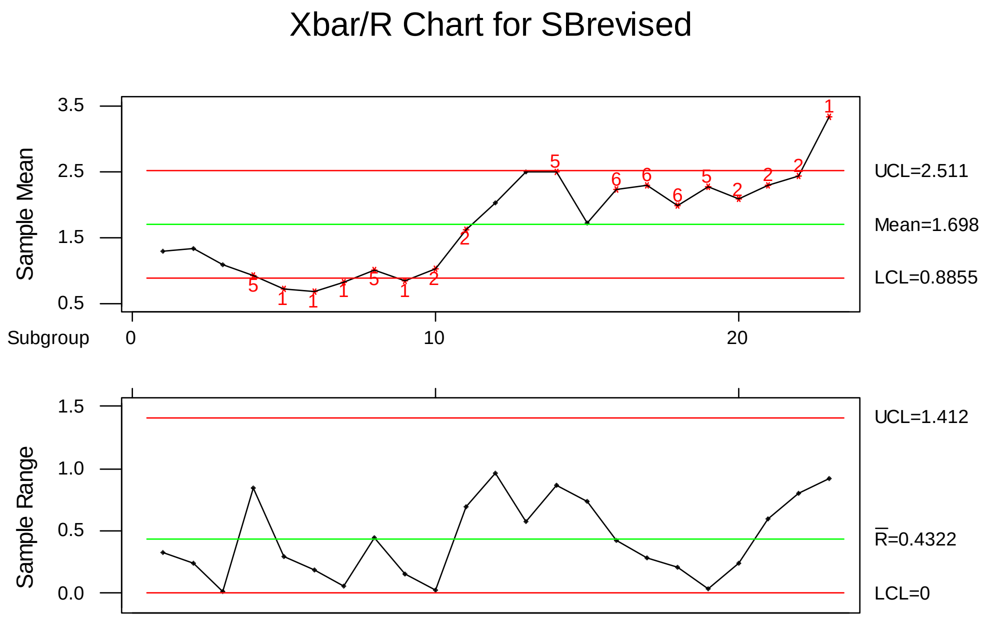

Figure 6. Revised Control Charts (Typical)

Similar techniques were used to develop the baseline control charts for the other shifts and locations.

ANOVAS were also performed using paint thickness as the dependent variable. Two factors were considered: Factor 1 was location and Factor 2 was shift. Analyses using the statistical software package, Minitab, showed that there were significant differences due to both location and shift. Specific results are not shown due to proprietary reasons.

The team focused a significant amount of effort on the Failure Modes and Effects Analysis (FMEA). Forty eight process steps were selected for investigation. Four in-house experts were identified and polled using a consistent data collection sheet. The experts included both operators and management. Their ratings were entered into the basic FMEA worksheet, and the RPNs were calculated based on rankings identified by Besterfield, et al [1] shown in Table 2.

Table 2. FMEA Rankings

Severity of Effect	Likelihood of Occurrence	Ability to Detect
10 Hazardous without warning 9 Hazardous with warning 8 Loss of primary function 7 Reduced primary function performance 6 Loss of secondary function 5Reduced secondary function performance 4Minor defect noticed by most customers 3Minor defect noticed by some customers 2Minor defect noticed by discriminating customers 1No effect	10 9 Very High: Almost inevitable 8 7 High: repeated failures 6 5 4 Moderate: Occasional failures 3 2 Low: Relatively few failures 1 Remote: Failure is unlikely	10 Cannot detect 9 Very remote chance of detection 8 Remote chance of detection 7 Very low chance of detection 6 Low chance of detection 5 Moderate chance of detection 4 Moderately high chance of detection 3 High chance of detection 2 Very high chance of detection 1 Almost certain detection

As an example, a potential failure in paint material (accident or transport failure) was evaluated as follows:
Potential Failure Effect Lack of paint consistency Severity of Effect rating 4
Potential Cause Dropped powder Likelihood of Occurrence rating 3
Current Control Lifting procedures Ability to Detect rating 3
The Risk Priority Number is the product of the three ratings. Severity*Likelihood*Detection = 36 = RPN

The FMEA RPNs ranged from 300s to 20s. The uncontrolled process steps were eliminated from further consideration. The chart was rearranged so that the largest RPNs were at the top of the list. Of the controlled process steps the five highest critical to quality factors were found to be

- Powder application - operator
- Cure process
- Powder application - spray gun
- Loading
- Unloading

The final project deliverable was a control plan based on current data. The team developed new standard operating procedures (SOPs) for several operations. Future work includes establishment of a plan for constant metrics, implementation of new SOPs, periodic process review, implementation of new metrics as needed, and eventually, project closure.

IV. Conclusion

An interdisciplinary senior design team was able to successfully complete a component of a Six Sigma project for a local industry client. Dr. Joan Burtner served as a technical advisor for the project that involved investigating ways to improve the powder-coat application process at a middle Georgia manufacturing facility. The industry client proposed the project as part of the facility's ongoing Six Sigma efforts. Following the DMAIC process, the team used process maps, cause and effect matrices, failure modes and effects analysis, and control charts to evaluate the process and recommend changes. The five highest critical to quality factors were found to be: Powder application – operator, Cure process, Powder application - spray gun, Loading, and Unloading. The final deliverable was a company-specific control plan based on available data.

References

1. Besterfield, D., Besterfield-Michna, C.B., Besterfield, G.H., and Besterfield-Sacre, M., 2003, Total Quality Management, 3rd Edition, Upper Saddle River, NJ: Prentice Hall.

2. Bossert, J., 2003, "Lean and Six Sigma—Synergy Made in Heaven." Quality Progress. 31-32.

3. Folkes, W. and Creveling, C. ,1995, Engineering Methods for Robust Product Design: Using Taguchi Methods in Technology and Product Development, Reading, MA: Addison-Wesley

4. George, M. L., 2002, Lean Six Sigma, New York: McGraw Hill.

5. Harry, M. and Schroeder, R., 2000, Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations. New York: Random House.

6. Pande, P.S., Neuman, R.P. and Cavanagh, R.R. , 2000, The Six Sigma Way: How GE, Motorola, and Other Top Companies Are Honing Their Performance. New York: McGraw-Hill.