Reduction of Variation in a Welding Process using Operational Six Sigma Methodology

Jayakumar Narasimhan and Erick C. Jones
Department of Industrial and Management Systems Engineering
University of Nebraska–Lincoln
Lincoln, Nebraska - 68588, U.S.A.

Abstract

In order to be competitive, companies must provide products with excellent quality. In most instances the better the quality, the more competitive their product becomes when they are competing for the customer's dollars. Six Sigma method proves to ensure good quality in industries. Statistical Process Control (SPC) can be used to track variations and identify the problems in the manufacturing processes. Some SPC tools are reactive, and can only be used to identify the problem after the occurrence. In addition, some of the process nonconformances are not detected through traditional SPC methods, like selective sampling inspection. This paper identifies the root causes of failure for a welding process at a manufacturing plant, and proposes to use Operational Six Sigma methodology to eliminate the problem. In contrast to other methods which measure and identify the nonconformance through destructive testing, a technique is proposed to use a mathematical model, which is later charted using SPC technique. The control chart for the mathematical model will identify the failure of the process in real time and will reduce/eliminate the testing process. The proposed Six Sigma methodology can be applied to eliminate nonconformance in other similar processes.

Keywords
Operational Six Sigma, Resistance Spot Welding, Statistical Process Control, Regression chart.

1. Introduction
A company located in the central USA is facing problems with the welding process. This problem sometimes affects the whole production system and needs immediate attention. A student group from the University of Nebraska–Lincoln was assigned to study the problem and provide a solution. This report describes the methodology applied by the process study group and elaborates the proposal made by them to improve the process.

2. Company and Process Background
The welding process under study is used to produce firm electrically conductive contacts which are used in circuit breakers. These electrical components are widely used around the world to regulate the power supply to home and industrial appliances. A circuit breaker functions like a fuse, to break a circuit path when the amount of current flows through it exceeds a predetermined value. Figure 1 shows the schematics of a circuit breaker. The contact in a breaker is an important component because any changes in the physical and metallurgical property will lead to malfunctioning of the whole system, causing damage to the electrical appliance and the equipments around.

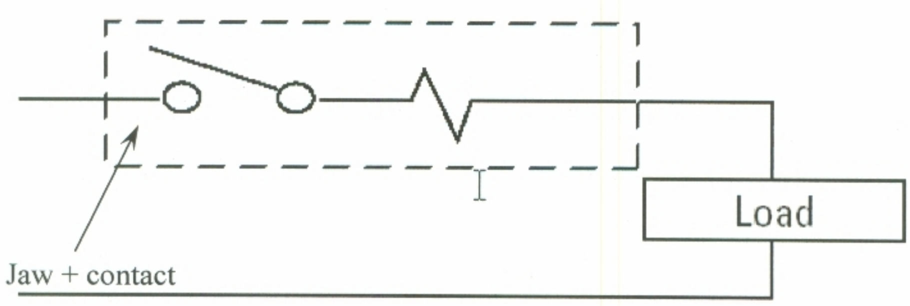

Figure 1. Schematics of a circuit breaker.

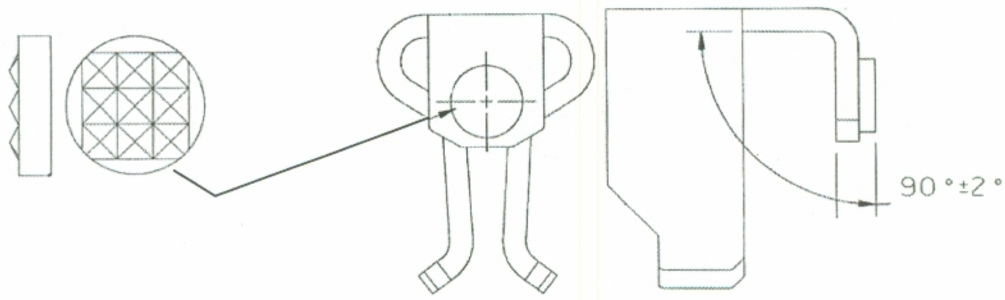

Figure 2 a. Contact with serrations. Figure 2 b. Jaw with the contact.

Figure 2 shows the jaw with a cylindrical contact that has serrated surface for instant melting to form a homogenous junction. The type of welding used to create this joint is classified as Resistance Spot Welding [7], where high current is allowed to flow through the material that needs to be joined. The applied pressure and resistance to the flow of current leads to a temperature raise that melts the surface between the contact and the jaw, forming a strong weld. The quality of weld can be measured in terms of shear strength and resistance to the flow of current. The company has specified that the contact must withstand a minimum shear force of 271 pounds and the maximum contact diameter after welding needs to be 0.165". A higher value for the shear strength is also specified because higher welding strength changes the electrical properties of the contact.

3. Problem Statement

The contact/jaw welding is a continuous production process and during normal production the operators of the welding equipment faced problems with the welded component. The operators experienced lots of scrappage due to variability in the welding strength and requested an immediate attention from the management, initiating the quality study.

4. Methodology

The student group studied the problem and opted to employ Operational Six Sigma methodology which is widely used in industries to eradicate these types of problem. Operational Six Sigma [1-3, 5, 8 and 11] was successfully implemented in both the manufacturing and the service industries. Many companies in both industries have deployed the process in various activities throughout their organizations. Six Sigma is a term used to describe a measure of quality control that is higher than what is perceived to be normal. Sigma is a statistical metric that measures variation from an expected outcome. Essentially, the six means that the process has no more than 3.4 defects per 1 million opportunities. According to Gluckman [6], an opportunity is any measurable outcome. Six Sigma is a methodology that is intended to reduce process variation to within some specified limit. Doran [4] states that sigma refers to the ability of a process to perform defect-free work. The increase in the numerical value that accompanies sigma suggests that the process is performing better and thus defects are less probable to occur. Consequently, Six Sigma strives to be a near perfect measure of quality in a process. It is a management philosophy or strategy that seeks to make an organization more effective and efficient. According to Rao [10], Six Sigma should result in a drastic reduction in the defect rates of a process. Six Sigma has a strategic component aimed at not only for developing commitment of higher management, but also to have active involvement. That strategic component is the responsibility of management to identify the key processes of their organization, measure their effectiveness and efficiency, and initiate improvements of the worst performing processes. Again, Six Sigma aims to reduce variability in a process. Operational Six Sigma follows the DMAIC principle which is the acronym for Define, Measure, Analyze, Improve and Control. Table 1 illustrates the task accomplished during the DMAIC steps. The following subsections describe the tasks performed at each step of the welding improvement process, under study.

4a. Define

The equipment that performs welding also performs several other manufacturing processes. Figure 3 shows the sequence of the manufacturing processes that are performed on the welding equipment. A continuous silver coated strip is stamped, formed, the contacts are welded and trimmed to make the component. The contacts are made of brass that is coated with silver. The above sequence of processes are carried out using two sets of assembly, one is located at the front of the equipment and other at the back. Therefore, the corresponding welds are called front and back weld, respectively. The objective of the Six Sigma study is to control and reduce the variability in the welding strength.

Table 1. DMAIC process.

Define	What problem needs to be solved?
Measure	What is the capability of the process?
Analyze	When and where do defects occur?
Improve	How can process capability be Six Sigma? What are the vital factors?
Control	What control can be put in place to sustain the gain?

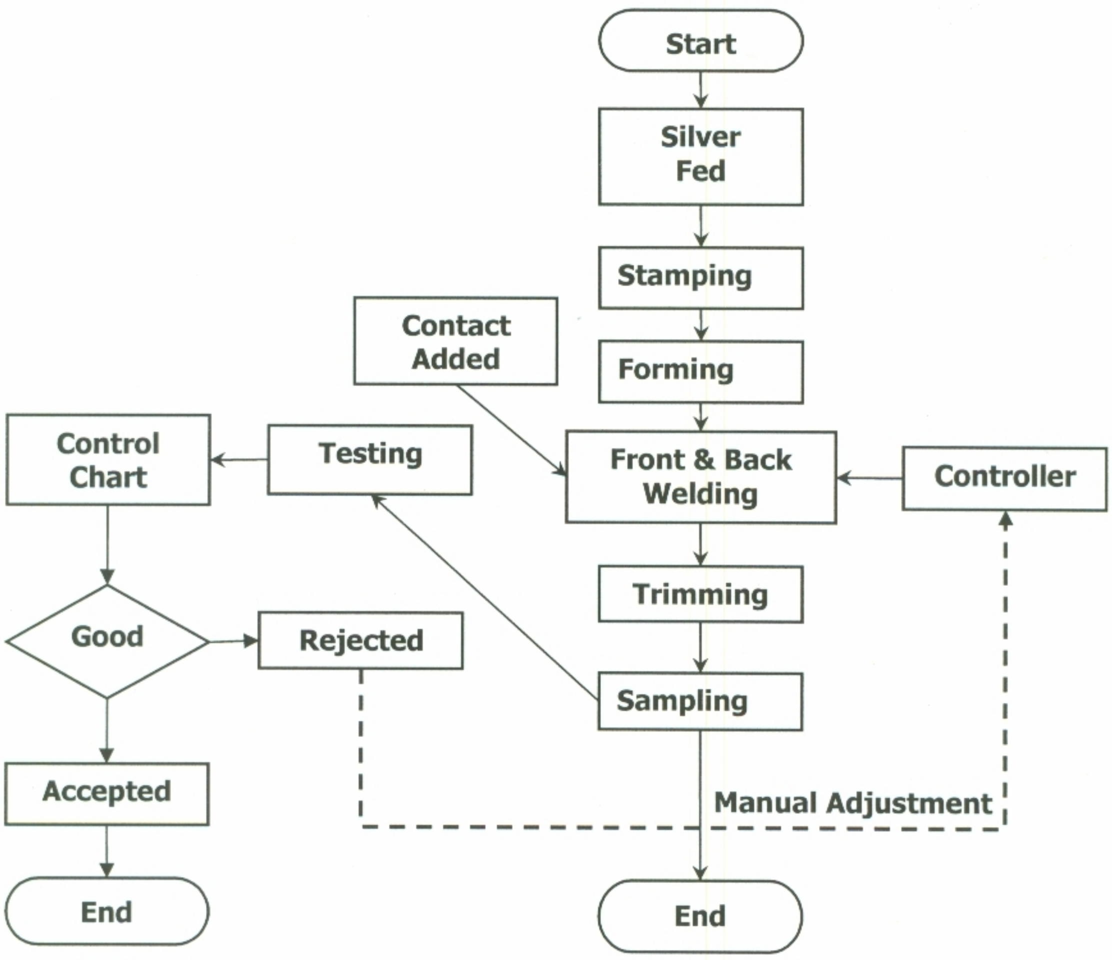

Figure 3. Sequence of processes on the welding equipment.

4b. Measure

The welding strength is measured in terms of the resistance the joints provide against the shear force (Shear Strength). The existing SPC process recommends picking 10 out of 5000 random components that are tested using shear tester. The parts are destroyed using shear force and the destruction-point values are plotted on a control chart. Figure 4 illustrates the existing inspection system.

4c. Analysis

The data collected are analyzed and X-bar charts are plotted. The front and back weld are controlled by separate processors; therefore the control charts were plotted separately for the two welds. From the control charts (Figure 5 and 6) it can be clearly seen that few data points were out of the control limits and the process is out of control.

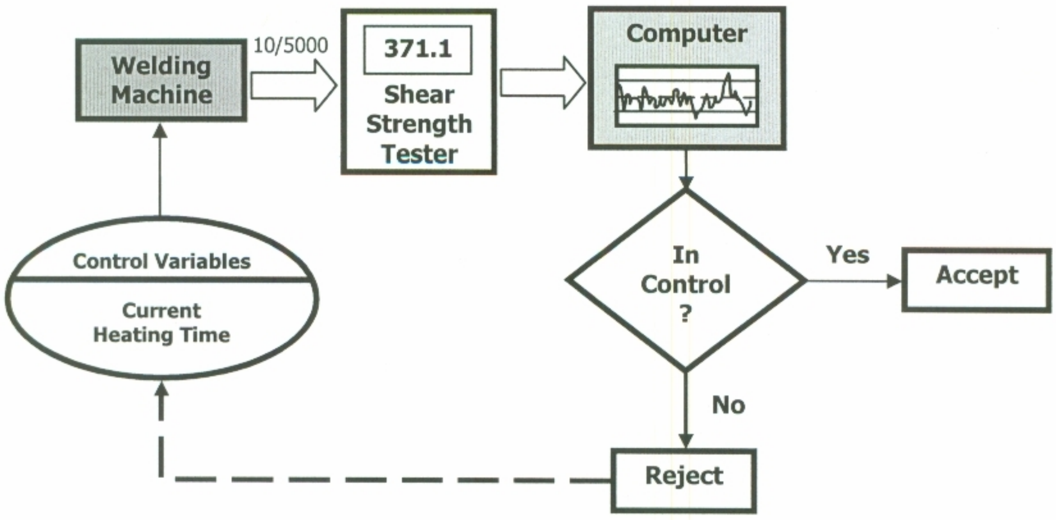

Figure 4. Existing Testing and Inspection System.

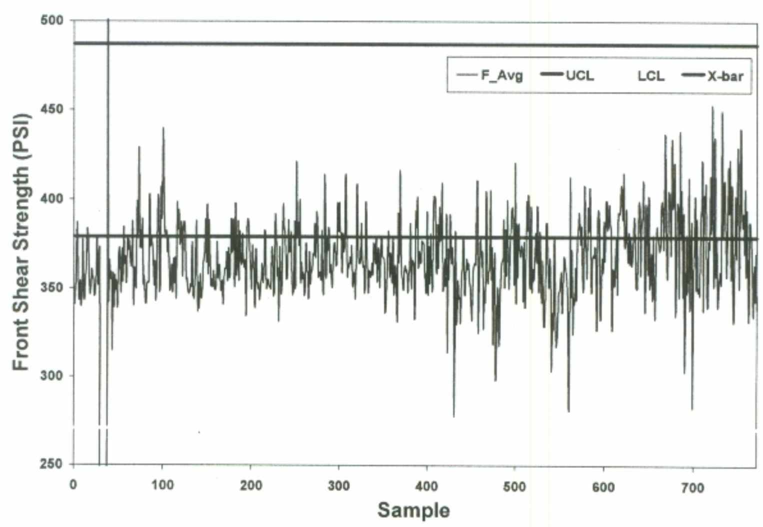

Figure 5. Front weld X-bar chart.

4d. Improve

In the improve stage, a new SPC system was proposed to improve the existing system. The disadvantages of the existing system were:

1. The occurrence of a defective part lead to scraping the whole batch.
2. There was no standard procedure to rectify the problem when it occurs.
3. The sample testing procedure is destructive in nature and the tested components cannot be used further.

The proposed SPC system uses a real time regression chart instead of an X-bar chart that will resolve the above problems in the existing system. To develop the regression chart a mathematical relationship needs to be established between the welding strength and the parameters influencing it. As a first step the parameters that influence the welding strength were identified that are shown in the fishbone diagram (Figure 7).

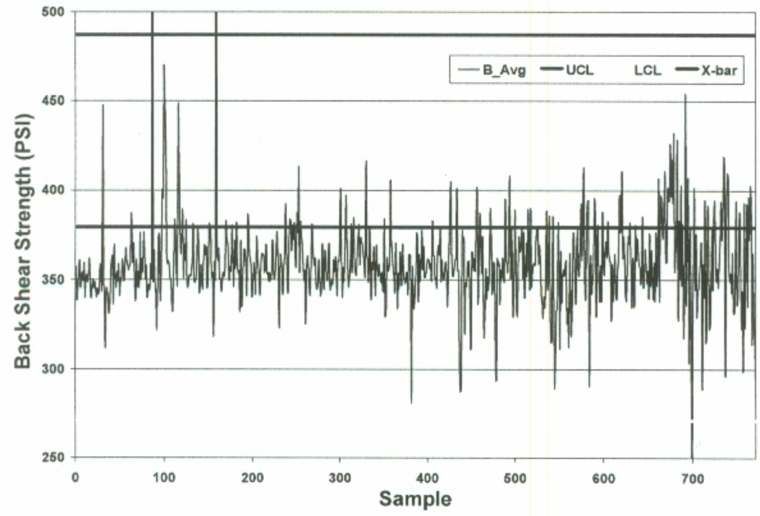

Figure 6. Back weld X-bar chart.

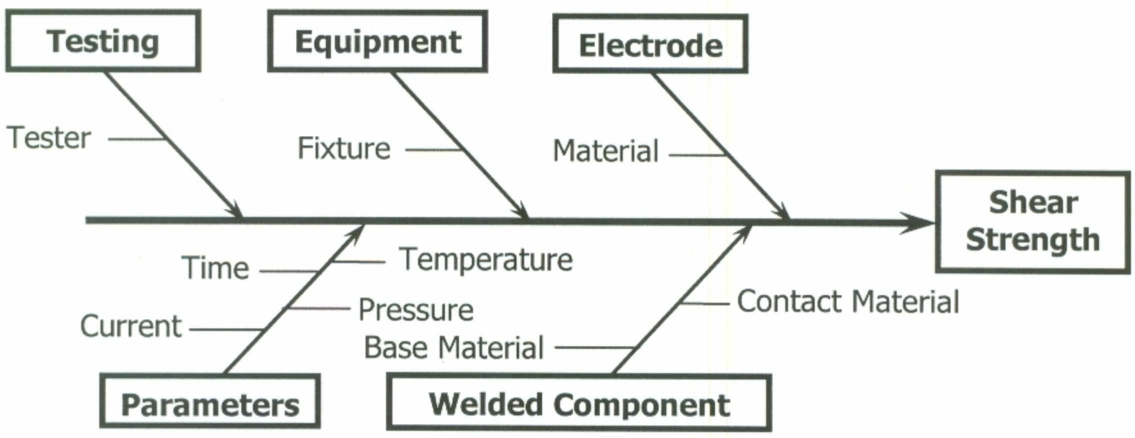

Figure 7. Fishbone Diagram.

In the above fishbone diagram most of the parameters can be assumed to be constant because they experience variations only due to the chance causes. Therefore heating time, current and pressure are the only variables that have effect on the shear strength. These three variables with three levels each are used in a statistically designed experiment [9]. Table 2 shows the treatment variables and their levels. The experimental run will include a full factorial design i.e., all possible combination of the factors with 4 replicates each.

Table 2. Variables and levels.

Heating Time (Cycles)			Current (K Amps)			Pressure (PSI)		
Low	Mid	High	Low	Mid	High	Low	Mid	High
120	140	160	9.6	10.4	11.0	2500	3000	3500

4e. Control

The regression function [12] obtained from the experimental runs will yield an equation as follows:

Shear strength of the weld (SS) = A+B* Heating Time + C* Current + D* Pressure

where A,B,C and D are fitted constants. Using an online data collection system real time run charts will be plotted for Heating Time, Current and Pressure, individually to monitor the variation in the values. A regression chart will be plotted using the developed mathematical relationship and the shear strength of the welded components can be estimated. The schematic of the real time monitoring is shown in the Figure 8. The operator now knows how to tweak the controllers with the help of the mathematical relationship during the occurrence of a defective component.

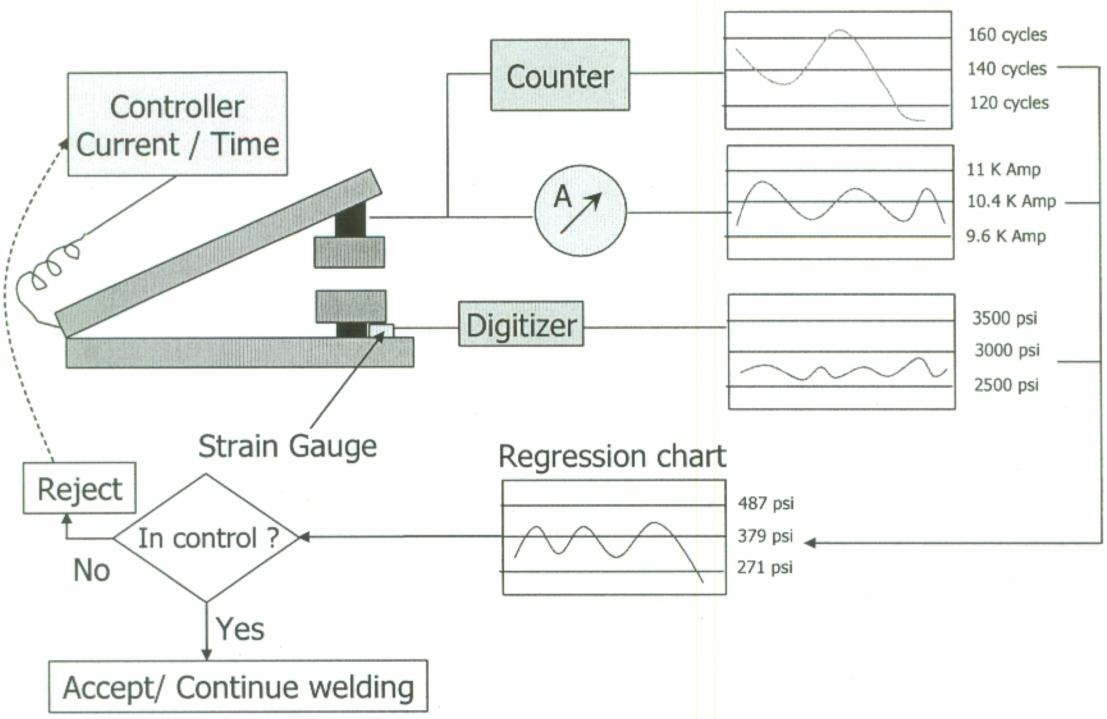

Figure 8. Real time monitoring system.

5. Summary

Operational Six Sigma methodology was selected to solve the variation problem in a welding process. The study group proposed a real time monitoring system by which the shear strength of the weld can be estimated without destructive testing. Due to 100% inspection, errors made by the selective sampling can be eliminated, reducing the scrappage cost. The implementation of this new system will pay for itself in a long run.

References

[1] Breyfogle, F., Cupello, J., and Meadows, B., 2001, Managing Six Sigma, John Wiley & Sons, New York.
[2] Caldwell, K., 2003, "Six Sigma Brings Control to the Shop Floor," Quality Magazine, 28-31.
[3] Chowdhurry, S., 2002, Design for Six Sigma, Dearborn Trade Publishing.
[4] Doran, C., "Using Six Sigma in the Credit Department," Credit Management, 32-34.
[5] Eckes, G., 2003, Six Sigma for Everyone, John Wiley & Sons, New Jersey.
[6] Gluckman, A., 2003, "Quality In, Workers Out? Companies Adopt Six Sigma," Dollars & Sense, 15-18.
[7] Groover, M.P., 2001, Fundamentals of Modern Manufacturing – Materials, Processes and Systems, John Wiley & Sons, New York.
[8] Joglekar, A., 2003, Statistical Methods for Six Sigma in R&D and Manufacturing, John Wiley & Sons, New Jersey.
[9] Montgomery, D.C., 1996, Design and Analysis of Experiments, 4th Edition, John Wiley & Sons, New Jersey.
[10] Rao, A., et al., 1996, Total Quality Management: A Cross Functional Perspective, John Wiley & Sons, New York.
[11] Shina, S., 2002, Six Sigma for Electronics Design and Manufacturing, McGraw-Hill, New York.
[12] Walpole, R.E., Myers, R.H., 2002, Probability and Statistics for Engineers and Scientists, 7th Edition, Prentice Hall.