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# STUDY OF FEASIBILITY OF SIX SIGMA IMPLEMENTATION IN A MANUFACTURING INDUSTRY : A CASE STUDY

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**Abstract-** This paper discusses the implementation of Six-sigma methodology in reducing rejection in a welding electrode manufacturing industry. The Six-sigma DMAIC (define– measure – analyse –improve – control) approach has been used to achieve this result. This paper explains the step-by-step approach of Six-sigma implementation in this manufacturing process for improving quality level. This resulted in reduction of rejection, and thus, reduced the Defect Per Million Output (DPMO) from 28356.96 to 1666.67. This had resulted in increasing the sigma level from 3.41 to 4.43, without any huge capital investment. During this study, data were collected on all possible causes and was analysed and thereby conclusions were made. Implementation of Six-sigma methodology has resulted in large financial savings for the industry.

**Keywords-** Six-sigma; DMAIC; Regression Analysis; Process Capability; sigma level; fishbone diagram; SIPOC diagram; Pareto Chart.

## I. INTRODUCTION

Six-sigma is a disciplined, systematic, data-driven approach to process improvement adopted by organisations world over. Motorola introduced the concept of six-sigma in the mid-1980s as a powerful business strategy to improve quality. Six-sigma continues to be the best-known approach for process improvement. Implementation of Six-sigma methodology has a significant impact on profitability and customer satisfaction, if successfully deployed. It takes users away from ‘intuition-based’ decisions to ‘fact-based’ decisions. This paper discusses a case study conducted in a welding electrode manufacturing industry with the aim of reducing rejection, and thereby increasing its sigma level, using Six-Sigma methodology. The application of the Six-sigma problem solving methodology, DMAIC, reduced the rejection and thereby improved productivity. Various statistical techniques were applied to analyse the data and to identify solutions at different stages.

## II. DEFINE PHASE

This phase includes identifying the key problem areas and defining quality characteristics.

### A. Problem Description

The problem encountered in the manufacture of welding electrodes is the large number of rejection of the units after manufacturing. The occurrence of rejection of welding electrodes was due to non-conformance of diameter with respect to the required standard specifications.

### B. Identifying Key Quality Characteristics (QCH)

The diameter of the welding electrode is a key QCH. The upper specification limit (USL) is 4.10 mm, and the lower specification limit (LSL) is 3.90 mm.

### C. Process Mapping

The process mapping with Supply-Input-Process-Output-Customer (SIPOC) provides a picture of the steps needed to create the output of the process. Fig. 1 shows the SIPOC diagram.

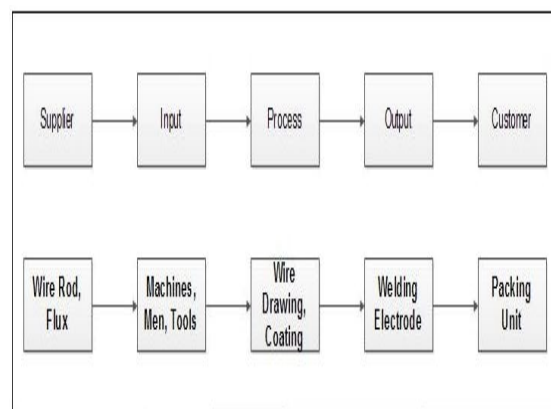


Figure 1. SIPOC Diagram

## III. MEASURE PHASE

This phase is concerned with selecting appropriate product characteristics, studying the accuracy of measurement system, making necessary measurements, recording the data, and establishing a baseline of the process capability or sigma level for the process.

### A. Probability Plot

The probability plot of the diameter readings of a 4x450 mm welding electrode lot, produced on a certain day is shown in Fig. 2. The plot shows that the diameter values do not follow normal distribution pattern, hence, needs to be studied upon more carefully.

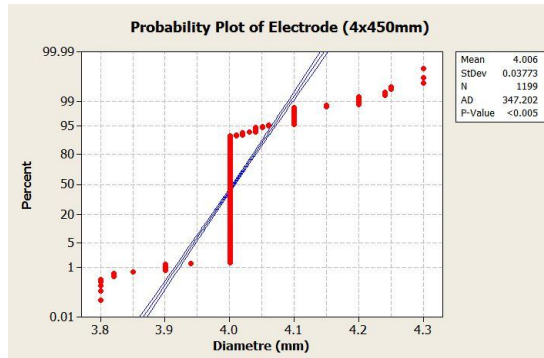


Figure 2. Probability Plot

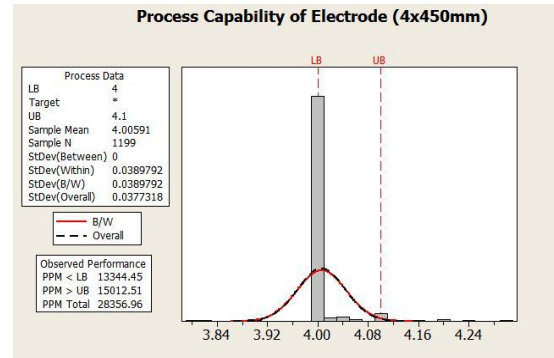


Figure 3. Process Capability of Electrode

#### A. Current Process Capability

A vital part of an overall quality improving program is process capability analysis by which the capability of a process can be measured and assessed.

The process capability index  $C_p$  enjoys a broad base of acceptance in the industry. The  $C_p$  is obtained from

$$C_p = (USL - LSL) / 6 \sigma \quad (1)$$

The standard deviation is estimated by

$$\sigma = R^- / d_2 \quad (2)$$

Where,  $d_2$  is constant related to sample size, while  $R^-$  is CL value in R chart.

Here,  $\sigma = 3.41$ .

The estimators of  $C_{PL}$ ,  $C_{PU}$  and  $C_{PK}$  are expressed by

$$C_{PL} = (x^- - LSL) / 3 \sigma \quad (3)$$

$$C_{PU} = (USL - x^-) / 3 \sigma \quad (4)$$

$$C_{PK} = \min(C_{PL}, C_{PU}) \quad (5)$$

$C_p$  value greater than 1 means that the process uses up less than 100 percent of the specification band, i.e. relatively less non conforming points will be observed. Whereas,  $C_p$  value less than 1, means the process uses up more than the specification band.

$C_{PK}$  value is less than  $C_p$  value, means that the process is off centred, but capable, and has to be confirmed with more no. of samples. Whereas,  $C_{PK}$  value less than zero means that the entire process mean lies outside the specifications, hence, the process is incapable.

The process capability chart for electrodes of diameter 4 mm is drawn. As per calculation, the values obtained are  $C_p = 0.05138$ ,  $C_{PL} = 0.01035$ ,  $C_{PU} = 0.00919$ , and  $C_{PK} = 0.00919$ .

The process capability plot is shown in Fig. 3. It can be seen that the process uses up more than the specification band. It can also be deciphered that the process is off-centred, but capable.

Other findings from the Measure phase are:

- Current Sigma Level = 3.41
- DPMO = 28356.96

## IV. ANALYSE PHASE

The objective of analyse phase in this study is to identify the root causes that creates the dimensional variation of the welding electrodes. The Taguchi methods are utilized in this phase.

#### A. Pareto Chart Analysis

Data analysis was carried out in this phase to find the reasons for rejection of welding electrodes. It arises due to defects viz., diameter variation, defective coating, eccentricity and moisture content. Pareto analysis on the various types of defects is shown in Fig. 4. It is found that diameter variation caused the major portion in rejection of the welding electrodes.

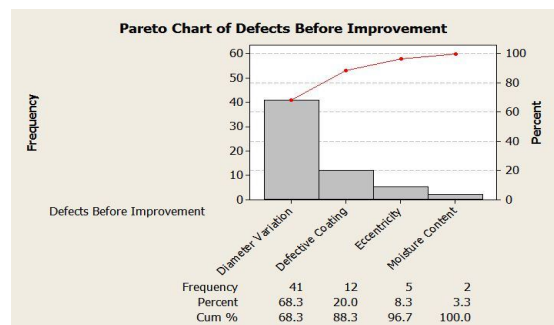


Figure 4. Pareto Diagram of Defects

#### C. Fishbone (Ishikawa) Diagram Analysis

The tool that is used for the analysis of the causes of variation of diameter of the welding electrode is the Cause-and-Effect diagram or fishbone diagram as shown in Fig. 5.

#### D. Regression Analysis

Data were collected on process parameters like silicate percentage, extrusion pressure ( $\text{kg}/\text{mm}^2$ ), baking temperature ( $^{\circ}\text{C}$ ), ratio of diameter of electrode to diameter of rod ( $D/d$ ), and void diameter (mm). The effects of the process parameters on the diameter variation were validated by a regression analysis. Table 1 shows the Minitab output of the regression analysis. Table 2 shows the ANOVA results.

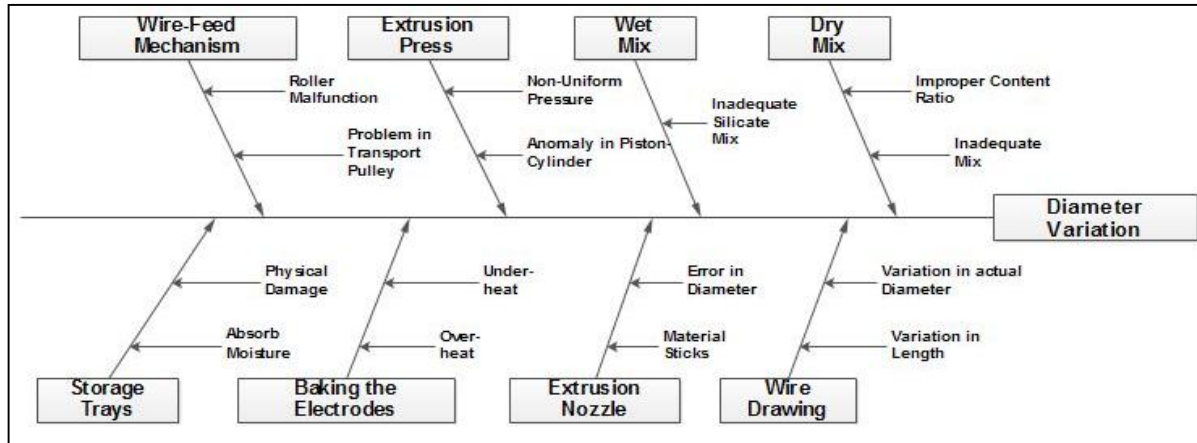


Figure 5. Cause-and-Effect Diagram

.Since, the p-values for void diameter and silicate percentage, from the regression analysis were found to be very less, it was concluded that these variables significantly results in the diameter variation.

TABLE I. : Minitab Output of Regression Analysis

The regression equation is				
Diameter (mm) = 4.74 - 0.0383 silicate % - 0.641 D/d + 0.150 Void Diameter (mm) - 0.000068 Baking Temperature				
Predictor	Coefficient	SE of coefficient	t-statistic	p-value
Constant	4.7425	0.5821	8.15	0.015
silicate %	-0.03832	0.01893	-2.02	0.180
D/d	-0.6415	0.5521	-1.16	0.365
Void Diameter (mm)	0.14998	0.03989	3.76	0.064
Baking Temperature	-0.0000677	0.0002760	-0.25	0.829
S = 0.00623757 R-Sq = 99.8% R-Sq(adj) = 99.4%				

TABLE- II : Analysis of Variance

Source	DF	SS	MS	F
Regression	4	0.039522	0.0098805	253.95
Residual Error	2	0.0000778	0.0000389	
Total	6	0.0396000		

### V. IMPROVE PHASE

During this phase, solutions were identified for all root causes selected during analyse phase. The feasible solutions were implemented and results were obtained.

#### B. Brainstorming Session

In this phase detailed discussions and brainstorming sessions were carried out. Solutions were identified for all selected root causes. The possible solutions are listed as under.

- Constituent chemicals should be accurately weighed for dry mix.
- Thorough mixing and accurate percentage of silicate is to be introduced in wet mix.
- Wire-drawing is to be carried out by skilled worker only.
- Nozzle diameter is to be checked frequently for wear and tear. Replace entire nozzle if diameter is more that tolerance limit.
- No materials should stick inside nozzle.
- Oven temperature must be between 250 to 300°C.
- Storage trays must be of proper condition. Electrodes should be saved from physical damage.
- Exposure of electrode to air should be for minimum time span. Packaging of electrodes should be done as soon as possible.

A risk analysis was conducted for identifying possible negative side effects of the solutions. No risk as such, has been associated with any of the identified solutions.

#### C. Process Capability After Implementation

This phase aims at adjusting the process mean on target. Process mean can be adjusted on target by improving the factors that have significant effects on the mean. The process capability chart of the 4x450 mm welding electrode drawn after the

implementation of the solutions is shown in Fig. 6. The DPMO of the process was found to be 1666.67 and the corresponding sigma level was calculated to be 4.43.

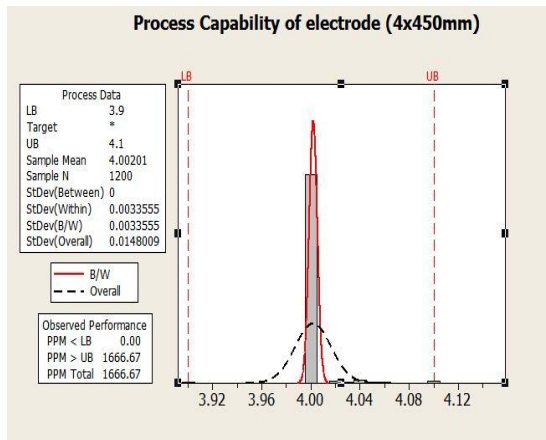


Figure 6. Process Capability of Electrode (4x450 mm)

D. Dot Plot

A dot plot which was drawn for comparing the process before and after the study is shown in Fig.7. The dot plot shows a significant reduction in dimensional variation after implementation of the study.

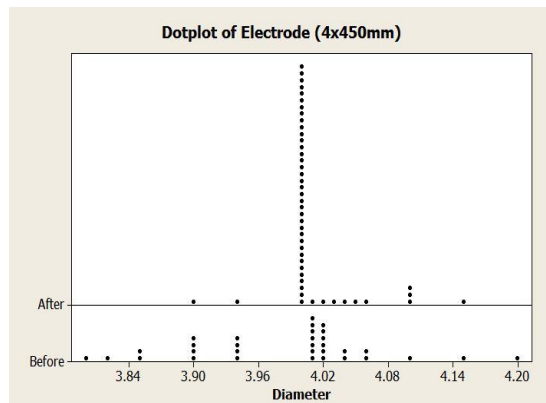


Figure 7. Dot Plot for Electrode Diameter

E. Pareto Chart After Improvement

After implementation of the solutions, the reasons for rejection were analysed with the Pareto chart. The Pareto chart after improvement is shown in Fig. 8.

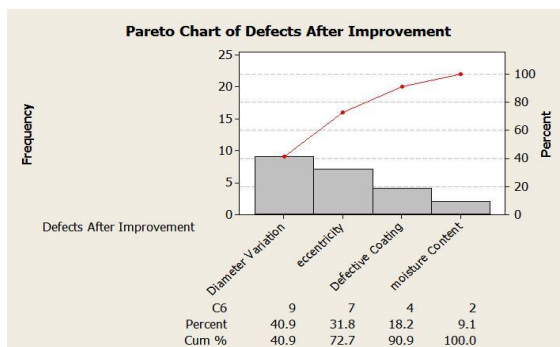


Figure 8. Pareto Chart after Improvement

VI. CONTROL PHASE

The real challenge of Six Sigma implementation is not in making improvements in the process but in sustaining the achieved results. In this phase, the process control charts and Pareto charts are regularly utilized for monitoring diameter readings. In addition, quantity and quality of silicate has to be maintained to produce proper quality coating material, which is a dominating factor causing unwanted diameter variation. Also, regarding the problem of nozzle wear, it is to be monitored that its diameter remains within specification limits, otherwise to be replaced by a new nozzle.

A. Visible Results

The implementation of the various tools and brainstorming sessions has resulted in the improvement of the manufacturing process, and also on the industry as a whole. The comparison of sigma level before and after undertaking the study is depicted in Fig. 9.

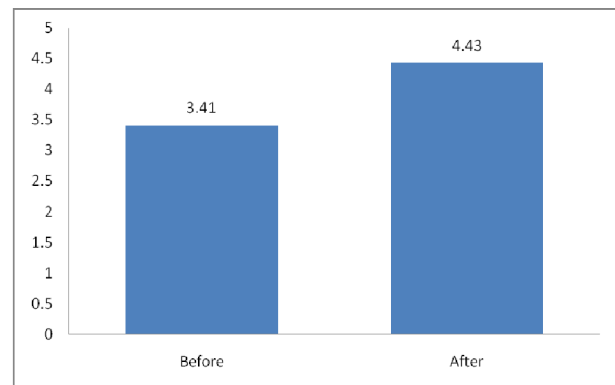


Figure 9. Comparison of Sigma Levels

VII. CONCLUSION

The paper is concerned with the detailed analysis of the problem of rejection of welding electrodes due to the variations in diameter of the manufactured units. Analysis was carried out with the help of statistical tools like normality testing, process capability analysis using process capability tools and studying the process capability ratios and fish-bone diagram.

The normality test carried out on the diameter values showed that the data was not normally distributed. The capability of the process was determined using process capability charts and ratios and it also throws light on some of the important facts concerning the performance of the manufacturing process at present and in future. The probable causes of the problem were deciphered by drawing and analysing the cause-and-effect diagram. Regression analysis helped in finding the severity of each causes. Pareto charts helped in analysing the reasons associated with the main defect, i.e.

variation of diameter of welding electrode. Some of the dominating factors causing rejection of the welding electrodes were the non-conforming diameter, resulting from improper nozzle condition and bad quality of coating material prepared.

To conclude we can say, the six-sigma methodology including Taguchi methods has proved to be an effective approach for improving the quality of the welding electrodes that are manufactured in the concerned industry.

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