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An Approach to Enhance the Sigma Level in Cable Industry by Using QC Tools and DMAIC Methodology: A Case Study

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Abstract

The Six Sigma approach has been increasingly adopted worldwide in the manufacturing sector for enhancing quality performance, making the process robust to quality variations and reducing defects level to less than 3.4 per million process, product or service opportunities (DPMO). This paper deals with analyzing and improving the quality level of Bangladesh Cable Shilpa Limited (BCSL), a renowned cable industry of Bangladesh by employing a six sigma-DMAIC (Define–Measure-Analyze-Improve-Control) based methodology where different quality improvement tools viz. Control chart, Pareto chart, FMEA (Failure Mode and Effect Analysis) Chart, cause and effect diagram have been used. The existing sigma level of this industry is 2.7 has been calculated by using Minitab software which is not satisfactory at all. Here a six sigma based framework has been provided to identify, quantify and eliminate sources of variation in different operational processes and improve the performance by establishing sustainable quality control plans to enhance the existing sigma level.

Keywords: DMAIC, Control Chart, DPMO, Six Sigma, QC tools.

1. Introduction

Bangladesh Cable Shilpa Limited (BCSL), is one of the most successful optical fiber and telecommunication cable manufacturing industries of this country. BCSL maintains its own Standard Operating Procedures (SOP) for providing a better quality product. Bangladesh Cable Shilpa Ltd. usually produces four types of telecommunication wire according to the customer requirements. BCSL started its commercial production in 1971-72, now produces all types of telecommunication copper cables and satisfies a major portion of the annual demand of cables in Bangladesh and also exports in abroad [2].

Quality is specifically measured in terms of defect rates and is assessed in terms of customer's perspective. Six Sigma is a set of techniques and tools for process improvement. It was developed by Motorola in 1986 [11]. Jack Welch introduced the concept of quality in General Electric in 1995 for the first time ever [11]. Today, it is used in almost all kinds of industries. Six Sigma simply means a quality ensuring measure that strives for near perfection. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects. A Six Sigma defect is defined as anything outside of customer specifications. Process sigma means the quality level of any particular process, can easily be calculated using a Six Sigma calculator. The term Six Sigma originated from the terminology associated with the statistical modeling of manufacturing processes. The real power of Six Sigma is simple because it combines people power with process power. If an organization is concern about quality and want to enhance the sigma level must have a well established quality plan which includes both quality measuring and controlling tools [1]. Six Sigma concepts helps measure the level of excellence in performance of any activity. This also measures the capability of the activity to perform defect free work. In fact, Six Sigma relies on normal distribution theory to predict defect rates of any activity being predicted. The level of sigma can be analyzed by two ways which are known as defected parts per million opportunities or defects per million opportunities (PPMO or DPMO). Six Sigma only can be achieved when it is possible to reduce the defect rate to 3.4 parts per million opportunities [4]. Over the years, Six Sigma has been evolved interestingly and become a customer-driven approach. The Six Sigma is a unique means of quality measurement, which can be applied irrespectively of the type, complexity and diversity of the processes and products. The attention is focused on the processes, as the final results depend on what happens during the processes [3]. Dr. Hurbert K. Rampersad and Brutu Madalina introduced Total Performance Scorecard (TPS) and also its application in the sales management [6][7].

The first job of implementing Six Sigma is to measure the current sigma level, so in our case we also had measured the current sigma level of BCSL and it was around 3 which is not satisfactory at all. The major issue of implementing six-sigma in any organization is the need of diagnosis of the critical causes responsible for the occurrence of the defects. Reducing those defects is the only way to increase the sigma level. Checking and eliminating defects is a continuous process and can be easily maintained by following DMAIC methodology which has been shown in the later portion of this paper.

2. Literature Review

The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and the reduction of the variations in the process, through the application of Six Sigma improvement projects. Six Sigma can be accomplished by implementing either DMAIC (Define, Measure, Analyze, Improve and Control or DMADV (Define, Measure, Analyze, and Design and verify).

Six- Sigma is a statistical measurement which is 3.4 defects per million and regarded as a management philosophy focused on eliminating mistakes, waste and rework. In addition to this, Six Sigma uses several statistical measures to analyze and interpret the data on processes and products. Historically a process was considered to be capable if specifications were +/− 3 standard deviations from the mean, which would result in about 3 defects per thousand opportunities if the process remained centered. Six Sigma follows a much more stringent approach to define process capabilities, and provides tools for mathematical computation of that capability. If a process is capable at six standard deviations, only 3.4 defects per million opportunities can be occurred (assuming a 1.5 standard deviation shift in the process mean) [5]. Six Sigma is a highly disciplined approach of decision making that helps people to focus on the improvement of the processes to make them as near perfect close to "zero defects" as possible [6].

More formally, Six Sigma can be described as an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific methods to make dramatic reductions in customer defined defect rates [1].

There are countless benefits of having employees trained on the Six-Sigma related processes. Some of the benefits include the followings: cost savings, increased productivity, lower frequency of defects, shorter cycle time, and improved customer satisfaction. One of the earliest success stories of Six Sigma had been begun with Motorola, the founders of Six-Sigma. At the Schaumburg, Illinois facility, ten years after implanting Six-Sigma, great successes had been seen. Like this two there are a plenty of stories of the success of the Six Sigma. Though Fredrick Taylor, Walter Stewart and Henry Ford played a great role in the evolution of Six-Sigma in the early twentieth century, it is Bill Smith, Vice President of Motorola Corporation, who is considered as the Father of Six sigma [7].

DPMO (Defects per Million Opportunities) is a measure of process performance. DPMO is the actual and observed number of defects which have been extrapolated to every 1,000,000 opportunities. Opportunities are actually the quality parameters against which the defects are identified. DPMO is not same as the defective Parts per Million (PPM) since it is possible that each unit (part) being appraised, may be found to have multiple defects of the same type or may have multiple types of defects. A part is defective if it has one or more defects. The number of defectives can never exceed the number of defects. If each part has only one characteristic that can be a defect, then DPMO and PPM will be the same. DPMO will always exceed or equal to PPM for a given yield or sigma level of performance.

$$DPMO = \frac{Number\ of\ defects \times 1{,}000{,}000}{Number\ of\ units \times Number\ of\ opportunities\ per\ unit}$$

Six-Sigma is composition of five steps which are represented shortly by DMAIC. Sequentially Define, Measure, Analysis, Improve and control are the steps which are mainly followed in six-sigma methodologies

The objective of this paper is to identify the problems that cause defects in various steps of production processes in a cable manufacturing industry and to improve the quality level of each manufacturing steps by reducing defects. This paper is mainly discussed with the six sigma based DMAIC cycle.

3. Methodology

The preface of implementing Six-sigma is very complicated job with several sequential steps which are related to observe carefully and concentrate deeply in all of the processes. These sequential steps have been discussed in the later portion of this study.

Data Analysis

Data has been collected from the factory of BCSL to pinpoint the problem. For the inspection of the quality level in the major four manufacturing stages of cable production (maintaining wall thickness, producing loose tube, inner sheet and outer sheet), data of the 15 consecutive days have been collected from the quality management department. Control chart has been used for assessing the ongoing quality of the cable industry. For BCSL, it has been plotted the X bar S chart in fig. 1,2,3,4 to illustrate the fluctuation of amperage for 15 consecutive days.

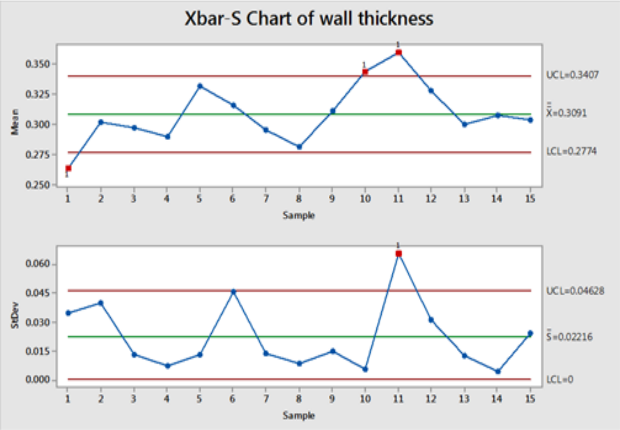


Fig. 1: X bar-S chart of wall thickness.

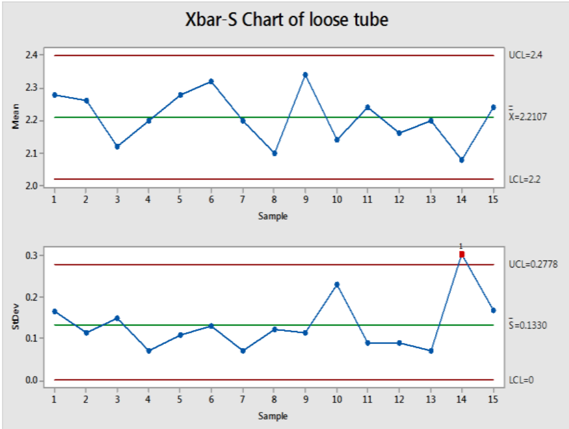


Fig. 2: X bar-S chart of loose tube.

X bar control chart has been used for the analysis of the quality data to examine the quality level of the major four manufacturing stages of cable production to know that whether the quality of those mentioned department is in under control or not. On the other hand S Charts have been employed to determine the process deviation from the mean (standard) or Target value.
An X bar Control Chart of maintaining wall thickness has been constructed as shown in Fig. 1, where UCL is 0.3407, Centre line is 0.3091 and the LCL is 0.2774. The wall thickness data of day 10 and 12 has been placed beyond the upper specification limit. The control limit has been fixed according to the customer satisfaction. The S-control chart has been selected to reduce the deviation of process at the same time. An X bar Control Chart of the production of loose tube has also been constructed as shown in Fig.2, in where UCL is 2.4, Centre line is 2.2107 and the LCL is 2.2. From X bar chart it is clear that all the loose tube data are within specification limit but in S Chart it can be shown that the loose tube data of day 14 is not in specification limit due to the process variability.

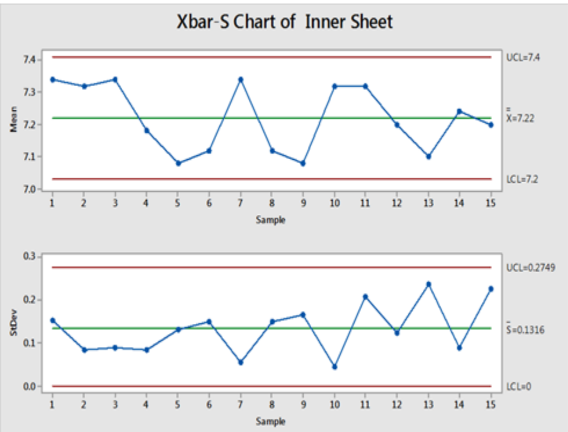


Fig. 3: X bar-S chart of inner sheet.

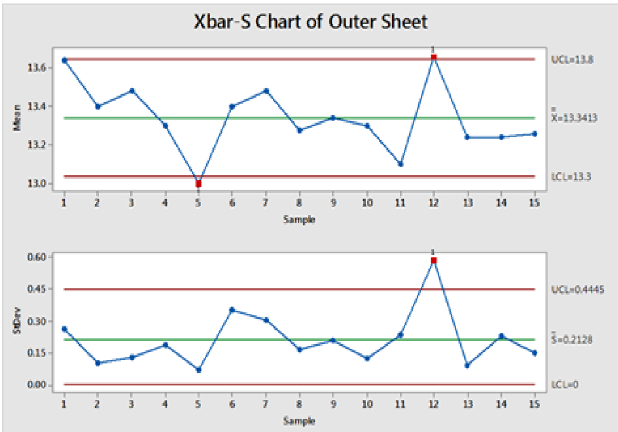


Fig. 4: X bar-S Chart of outer sheet.

X bar and S Control Chart of producing inner sheet has been constructed as shown in Fig. 3, where UCL is 7.4, Centre line is 7.22 and the LCL is 7.2 of the X bar control chart where all the data remains within the control limit. From S Chart it is clear that there is no process variation in this process as all the data remains in control limit. X bar and S Control Chart of producing outer sheet has also been constructed as shown in Fig. 4, where UCL is 13.8, Centre line is 13.3413 and the LCL is 13.3 of the X bar chart. Here two points are out of control in X bar Chart, but in S-chart there is one point plotted outside of the control limit.

DMAIC

to implement six-sigma it is needed to follow DMAIC approach step-by step. The DMAIC is a basic component of Six-Sigma methodology- a better way to improve process by eliminating the defect rate in the final product. The DMAIC methodology has five phases: define, measure, analysis, improvement, and control. These five phases of DMAIC have been followed as the solution maker in this study.

PROCESS DEFINATION

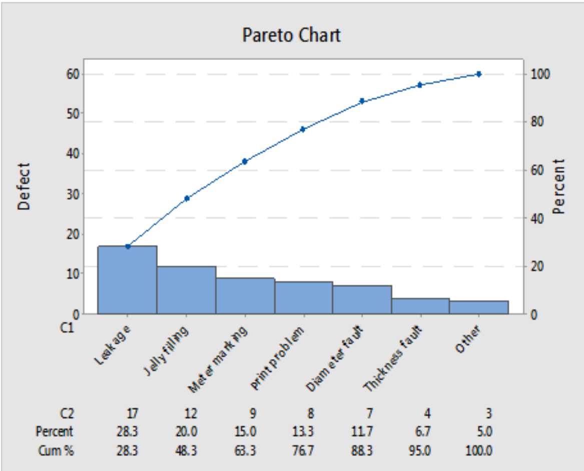
Define is the first phase of the DMAIC methodology of Six Sigma. The purpose of this phase is to define the problem, goals of the project and the process that needs to be improved to get higher sigma level. In this stage, the process which is needed to be improved is identified by proper investigation. Flowchart has become a key tool in the development of information systems, quality management systems, and employee handbooks. Here in this stage the processes are clearly identified and the critical processes for improvement are recognized.

PROCESS MEASUREMENT

In this measurement stage, different variables are identified for the accurate measurement of the Sigma Level and defects. As it has been tried to improve the sigma level of the organization, initially the present sigma level has been measured by using an Excel based sigma calculator and it was found that the present sigma level of the studied organization not satisfactory and it was 2.7 only. Hence, to improve this level, different quality improvement tools have to be employed and the organization should be needed to set a milestone to achieve.

Table 1: Sigma calculation

Total Checked	***470***
No. of Defectives	**49**
% Defectives	**10.43%**
DPO	**0.10425532**
DPMO	**104255.32**
Sigma level	**2.7**



. **Fig. 5:** Pareto Chart

Pareto Chart which is a bar graph has been used to graphically summarize and display the relative importance of the differences between groups of data. The lengths of the bars represent frequency and have been arranged with longest bars on the left and the shortest to the right. In this way the chart visually depicts which areas are more significant. In this research, the major causes or types of defects were identified through Pareto Chart. The chart was constructed by the Minitab Software. Fig. 5 shows a pareto chart in which major sweing defects and their severity have been displayed.

PROCESS ANALYSIS

The purpose of this phase is to target the improvement opportunities by taking a closer look on the different processes. Process problems and inefficiencies have been identified by root cause analysis. At the measurement phase eight major types of defects have been identified and the target of this phase is to find out all the potential causes of those defects. It is a very important stage to consider because lack of proper analysis may lead the process in a wrong way which will cause deviation from the main functions of improvement. In this stage, different basic tools of quality are preferably used to analyze the real condition of the processes.

A cause - effect diagram is drawn to analyze the potential root causes of different problems occurred in different stages of the production process. Cause - Effect diagram is a chart that identifies potential causes for particular quality problems as shown in Fig 6. They are often called fishbone diagram. These causes could be related to the machines, workers, measurement, suppliers, materials, and many other aspects of the production process.

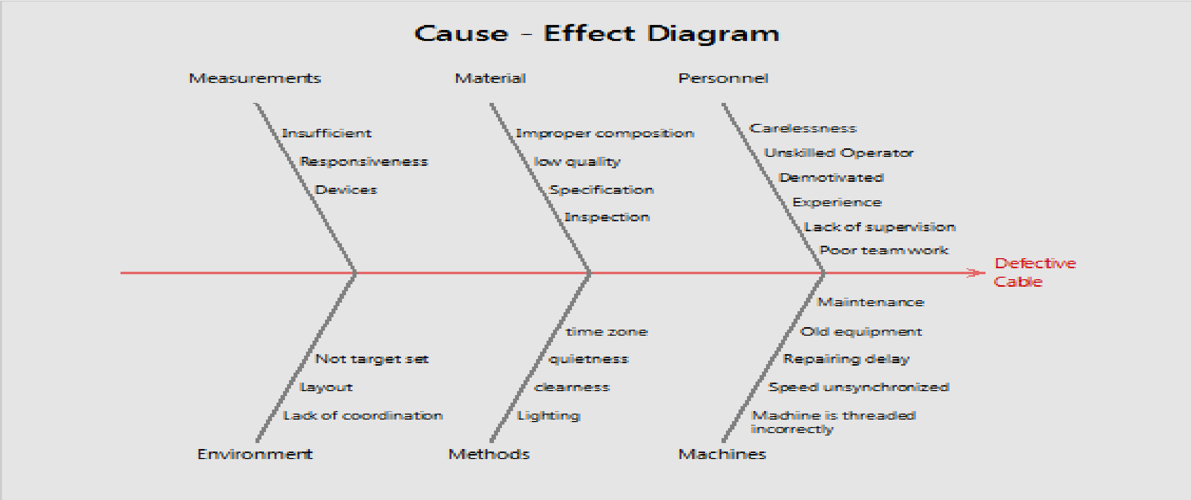


Fig. 6: Cause – Effect Diagram

Cause - Effect diagrams is constructed based on the root causes identified by the online inspection. Total 470 pieces were inspected directly and 49 defects were found. The causes behind the defects were also identified immediately. There are some vital causes shown in Table 2, which have the highest frequency of occurrence and are mainly responsible for the defects.

Table 2: Root Cause analysis

Sl No.	*Root Causes*	*Suggested Solution*
1.	Carelessness	Improve Supervision
2.	Lack of skills	Adequate training
3.	Poor team work	Proper interaction
4.	Maintenance	Make sure the machine work properly
5.	Old equipment	Change the old equipment over new ones
6.	Repairing delay	Repair as early as possible
7.	Insufficient	Make sure the cables are sufficient
8.	Devices	Check every devices before working
9.	Lighting	Provide adequate lighting
10.	Cleanness	All devices should be clean
11.	Low quality	Change into high quality materials
12.	Inspection	Proper inspection must be done
13	Low speed	Starts with low speed then gradually increase

PROCESS IMPROVEMENT

In this stage, improvement strategies are developed for achieving the desired goal. According to the analysis, perfect measures should be taken to progress the current situation. As the major concern is to implement six-sigma approach in the BCSL to improve current sigma level, it is highly needed to diagnose the critical issues responsible for this defect. For this reason, Pareto analysis is performed for different stages of production viz. maintaining wall thickness and producing loose tube, inner sheet and outer sheet to precisely identify the responsible factor of high defect and this is shown by Pareto charts in fig. 5.

PROCESS CONTROL

After taking appropriate actions for improving the process, it has been checked again whether it is under control or not, through checklist. On the basis of the results of this assessment, previous steps may be repeated several times to achieve the desired level. It is not possible always to get success at the first time, so recurring of all the steps will lead the process gradually at the preferred point. Here the major defects have been identified and partially reduced in amount. Now the real challenge is to sustain the improvements and improve the process continuously. So, this research made a sustainable control plan to sustain the improvements and make the process improving continuously.

4. Discussion

Minimizing defect is very important for ensuring the quality of products. The main purpose of this study is to increase quality level by decreasing the defects which will in turn raise the sigma level. As the minimization of defects is a continuous process further implementation of this methodology will help the company enjoying more reduction on defect rate and improvement on productivity. Though this case study has been conducted in a cable manufacturing organization, the procedures will be suitable for any manufacturing organization. During the study not all the information had been collected instantly, but some previous records have been also used for better understanding. Here in this paper, the direct implications of using six-sigma are not shown practically, but the pathways to implement them are discussed well. Due to time constraint, management could not be able to implement all of our suggestions. But they implemented some of our suggestions in short time-frame as a pilot run and found some improvement. All the charts and diagrams used here are drawn carefully to show the real scenario of the case organization. The organization is trying itself to improve its quality by reducing defects, but without using appropriate tools and techniques, it is almost impossible to make that happen. The management of BCSL has been satisfied with the Six Sigma – DMAIC based methodology discussed in this paper and ensured us that they will implement this procedure in large scale in recent future.

5. Conclusion

The six-sigma framework provides an impetus for establishing best quality practices in the organization. The primary reason for the success of Six Sigma is that it is not just a collection of tools, but it provides a systematic approach for quality and process improvement. This paper had identified the present sigma level and quality positions of the BCSl and compared it with the standard value. Future performance enhancement programs are based on a performance benchmark which has also been provided by this study.

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