Implementation of Statistical Process Control Techniques to Reduce the Defective Ratio: A Case Study

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Abstract

In this research, some of the statistical process control techniques were applied on a real case study from industry to reduce the product defective ratio. The company was suffering from the absence of supervision of quality control measurements and monitoring, which increased the variability where the number of defective bags increased with time without taking action. The average loss of material was around $330, which is not accepted by the quality managers. The control charts showed that most of the defects in bags occur in the bag length with a percentage of 56%. Pareto diagram presented the mismatching of triangular pockets, hole perforation and overlapping to be most frequent defective bags.

Keywords: Statistical process control, Capability index, Normality test, Cement bags manufacturing, Quality control

1. Introduction

In nowadays world market, quality plays an important role in many manufacturing and service companies to gain the competitive advantage. Product quality can be defined as meeting and even more exceeding customer requirements and expectations. The only way to being successful and competitive is not staying at the past performance and this is done by the continuous improvements of the process [1]. To achieve and maintain continuous improvement, companies should follow Statistical Process Control (SPC) strategy. SPC is one of the techniques used in Total Quality Management (TQM) for controlling, monitoring and managing a process either manufacturing or service through the use of statistical methods [2].

- Histogram
- Check sheet
- Pareto diagram
- Scatter diagram
- Flowchart
- Control chart
- Fishbone diagram

As long as we have not reached perfection or zero defects, at the best price, there will be an opportunity for improvement. Moreover, quality illnesses generally can be cured and optimized by using combinations of statistical techniques. Effective implementation of SPC techniques requires the proper climate of management having a good understanding of such techniques which provides SPC training and education for labor and aware them about the key factors that will make application successful. However, the implementation of SPC in Egyptian Small and Medium Enterprises (SMEs) that have difficulties due to the lack of awareness of both management level and labor level. Rungasamy et al. [3] derived a research based on a survey of 33 manufacturing SMEs showing that the most important critical success factors for SPC implementation are management commitment, control chart, teamwork, and quality training while the least important factor is the use of pilot study. Shari et al. [4] followed these factors proposed five recommendations to reduce defects and improve product quality in plastic packaging manufacturing company using SPC techniques. Implementation of SPC techniques makes it possible to control variation and prevent not only defective products but also services and defect here, is a failure to meet customer requirements and satisfaction. Ross [5] implemented SPC techniques in a medical organization and reduced the medication times that failed to meet the desired standard. With the use of histogram and capability process index, Das [6] conducted ANOVA model and found the existence of significant different among cement packing nozzles and the stochastic nature and economic factors of production were taken into account to derive the optimum economic setting of the packing process. Pavol [7] conducted a response plan to eliminate the root causes of the defective in furniture business using SPC techniques. Remy et al. [8] carried on SPC techniques, orthogonal array and capability process index to reduce the variability in tomato paste filling process and achieved 5.28 sigma process quality, in the addition that the process had only 77.49 parts per million (ppm) out of specification. Li et al. [9] used control charts, Pareto diagrams and capability process index to improve the bonding strength of tape-automated bonding (TAB) technology in super twisted noematic liquid crystal display (STN LCD) module manufacturing by double-process control and he was able to increase average bonding strength from 662.46 to 681.58 and also increased the process capability index from 0.83 to 1.35. Smeti et al. [10] used control charts for quality improvement of treated water and ensuring that it reaching to customer within the control limits. Sibalija et al. [11] used SPC techniques and capability process index to rank and analyze the defects in the manufacturing of automatic enameling of pots and they derived the optimal process setting parameters. Madanhire et al. [12] investigated the use of SPC techniques in Can manufacturing firm to improve quality and cost effectiveness. They derived some adjustment, new machine setting parameters and suggested recommendations to improve product quality. Using SPC techniques, Olmi [13] tackled the problem of high defect rate in the production of coffee valves and he proposed the optimum strategy to improve production with predicting the achievable defect rate. Nizam et al. [14] implemented SPC in eight manufacturing companies showing that the implementation of quality SPC has encountered some barriers in SMEs because they are unable to afford high technology system and involved high cost and prefer to use manual system using paper and pencil. While SPC techniques implementation was useful in the other companies, they were able to detect abnormality, reduce variations, reduce customer complaint and maintain stability of process. Das [15] implemented SPC technique in an integrated aluminum industry who suffering from poor customer acceptance of Webstock which used to produce toothpaste. He obtained the optimum condition of the process parameters using design of experiments and as result of implementation of these recommendations, the dragging problem was reduced

In this paper, we apply SPC tools on an actual case study of a cement bags factory. We collect and analyze data to make full analysis for the process and providing recommendations and suggestions for reducing percentage of defective bags. The problem is that the company loses around (330 $) 1.8 % of Kraft paper and glue per day which is not accepted and requires proper solution taking into consideration the economic perspectives.

The remainder of this paper is as follows: section 2 presents the used methodology, section 3 gives the applied case study, section 4 demonstrates the results, section 4 highlights some insights and recommendations and conclusion

2. Methodology

a) The proposed methodology is depicted in figure 1. First, the process is identified and sufficient data is collection and information is gathered using questionnaires and interviews to grasp the problem and evaluate the used statistical methods [1]. Second, the key product characteristics and what is critical to customer are identified [3]

Process capability refers to the uniformity of the process. Obviously, the variability of critical-to-quality characteristics in the process is a measure of the uniformity of output[16]. There are two indices must be taken into consideration while measuring process capability are $C_p and\ C_{pk}$

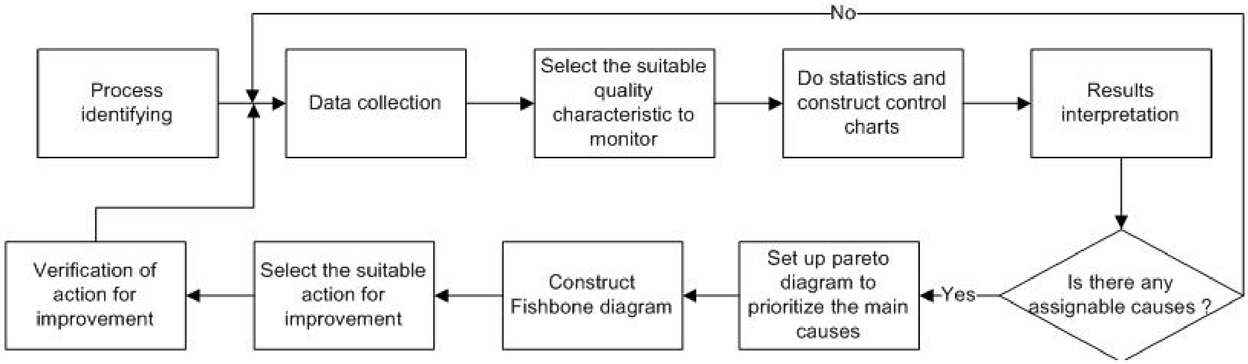

Figure 1 SPC implementing steps

- $C_p index$

In order to manufacture within a specification, the difference between the USL and the LSL must be less than the total process variation. Clearly, any value of C_p below 1 means that the process variation is greater than the specified tolerance, so the process is incapable. For increasing values of C_p the process becomes increasingly capable[2].

$$C_p = \frac{USL - LSL}{6\sigma}$$

- C_{pk} index

An index that takes into consideration the process centering in which how far the process mean from the center and, also the process variation[2].

$$C_{pk} = \min[\frac{\mu - LSL}{3\sigma}, \frac{USL - \mu}{3\sigma}]$$

b) Normality test

To construct control charts and process capability it is necessary to prove that data collected is normally distributed.

3. Case study

Cement production considered one of the most important strategic industries in our country. Egypt ranked 14th among the world's largest producers of cement by the end of 2014 with a production volume of 40 million tons, out of a total of 3400 million tons of world production. This huge production gives us the motivation to carry out this study. Cement bags manufacturing is one of the tools that serve on the production of cement. The methodology is applied on a case study of cement bags factory in a multinational company that considered to be the oldest company in the Egyptian market since 1986[17]. That is why this company suffering from many defective products

Absence of supervision for quality control measurements is increasing the variability and the average loss of material is around (330 $) which is not accepted. So It's clear that the main way to solve these problems is one of the following choices:

a) "Exchanging the current production line by a new one with high quality, fewer defects, high efficiency" and this solution is very expensive around 3.5 million $, and it is totally rejected due to limited budget.

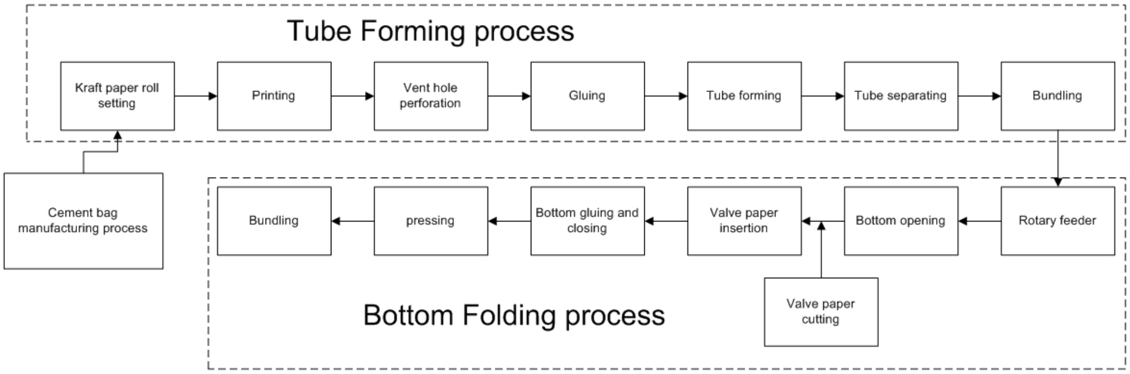

Figure 2 Cement bag manufacturing process

b) "Using different methods during producing bags such as SPC techniques" and it is the cheapest way to achieve continuous improvement. This will facilitate to determine the cause of the variation correct any problems that appear before they become unmanageable.

The company produces cement bag with a length of 60 cm with valve width of 9.5 cm and another valve width of 9.5 cm. A schematic diagram was drawn to show the other specification that is critical to customer and required to be inspected.

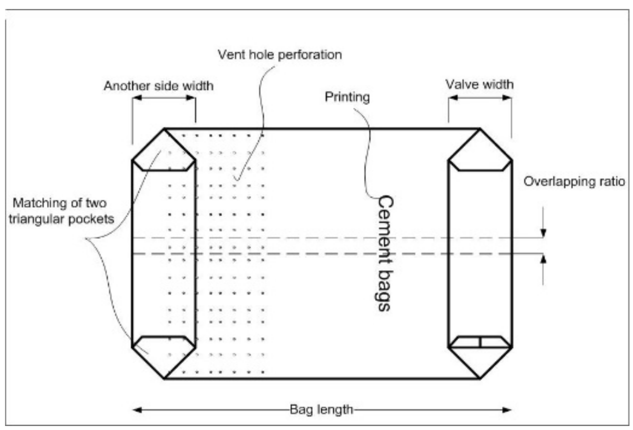

Figure 3 Cement bag specification

Our case study was launched for 4 months of 2017 April, May, June, and July. Two samples of four bags are taken a day randomly every single shift. The work in the company is going on with two shifts, morning shift and mid-day shift. The sample is taken for 25 working days per month. The company has four production lines (A, B, C, D).

$$N = 1^{sample,m} \times 8^{sample\ size,m} \times 2^{shift} \times 4^{machine} \times 4^{month} \times 25^{day} = 6400\ bag$$

Check sheets are used for data collection and the criteria for rejection of the collected data are checked for variables and attributes. Bag length, valve width, another side width is check for the variable characteristic. While the attribute characteristic, the bags are checked for color, vent holes, matching of the two triangular pockets, gluing and printing. Xbar and R control charts were carried out for the variables characteristics. 8 samples were checked daily, along the study, of sample size n=8 bags with control limits of $\pm 0.2\ cm$ where the value of control limits ($\pm 0.2\ cm$) is set as result for survey carried out for the customers recommendations as many customers dissatisfied with this high limit and also from competitors as there are many cement bags factories established recently in the Egyptian market. Fishbone were set up for the main reasons of defective for Bag length. For attribute characteristics P control charts and also Pareto diagram was set up to identify the 20% of the modules which yield 80% of the issues [2]. Fishbone diagrams were set up for the main reasons of defective of attribute characteristics.

4. Result and discussion

The data collected for variable characteristics is proved to fit normal distribution as shown in the figures below.

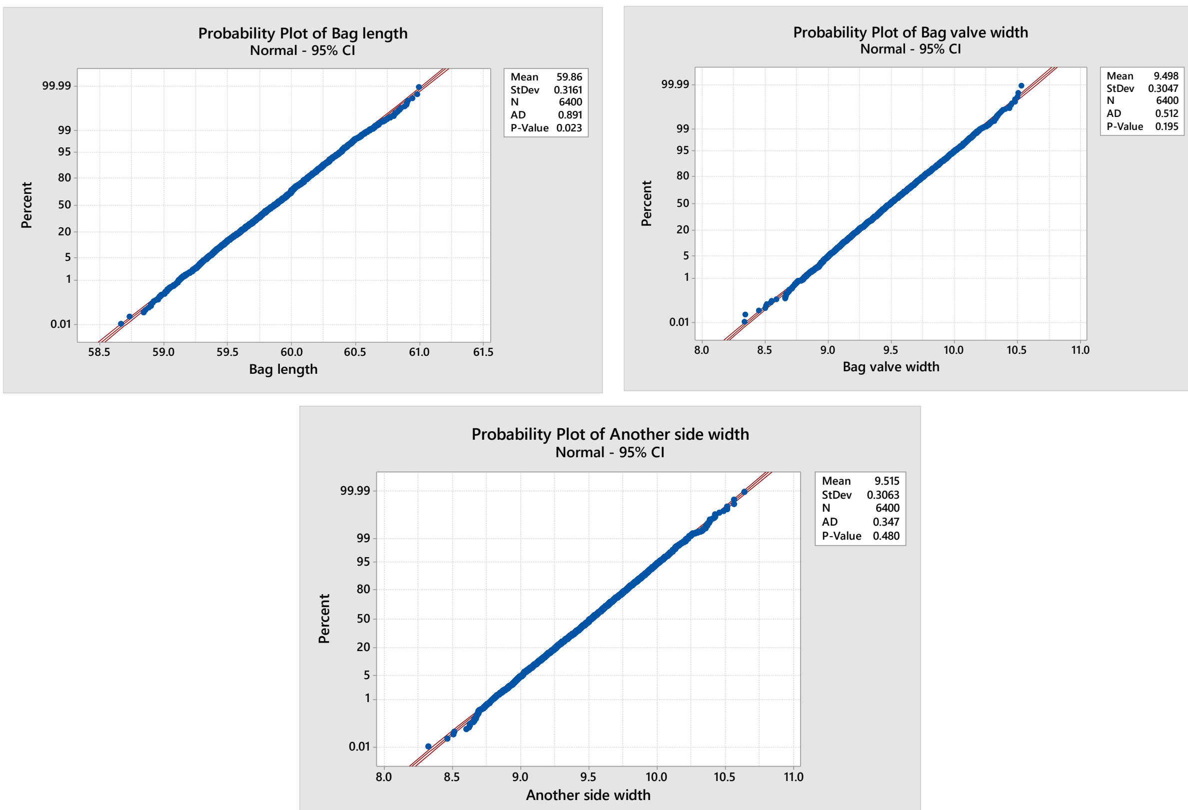

Figure 4 Variable characteristics normality plot

Cement bag dimension behavior during the four months is shown in figure 5, where the average value of bag length is located nearly at 59.8 cm with $C_{pk} = 0.07$ meaning that the process center is moved toward the left and contributes in a great extent to process capability to meet the desired specification and it's imperative to do significant modifications to reach the proper quality. Bag valve width and another side width took the same behavior of bag length where the value of C_{pk} for both of them were 0.22 and 0.21 respectively.

Figure 7 shows the irregular behavior of cement bags dimensions and fluctuations along time of the random data collection. From the figure, 453 samples were out of control for bag length dimension, about 3624 bag of total 6400, with ratio of 56% defective and 302 samples was out of control for valve width dimension, about 2416 bag of total 6400, with ratio of 38% defective and 312 samples was out of control for valve width dimension, about 2496 bag of total 6400, with ratio of 39% defective. So, the higher percentage of bags defective due to bag length so the total defective percentage is 56%.

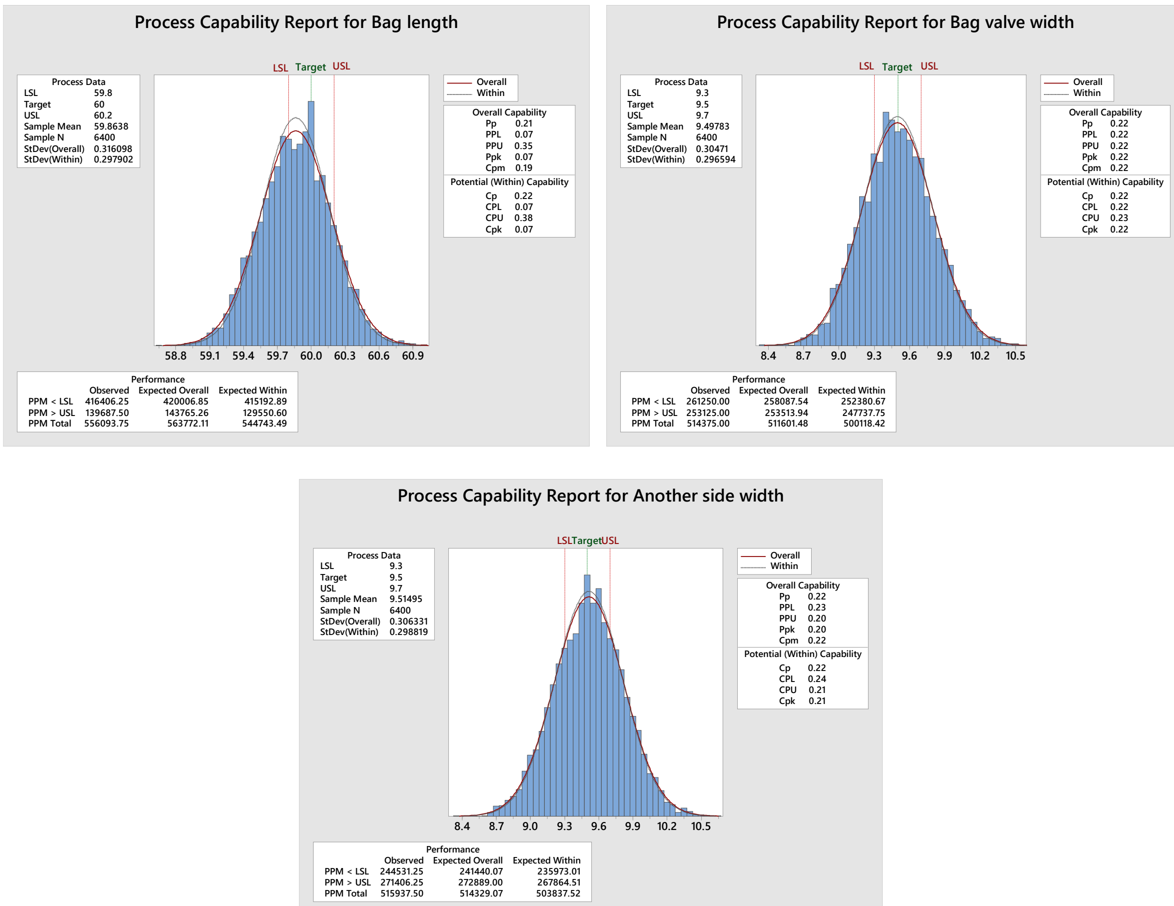

Figure 5 Process capability plots for the variable characteristics

From figure 8, about 2023 bags were found to be defective with percentage 31.6 % . Pareto diagram was constructed for attribute characteristics where mismatching of triangular pockets, hole perforation, and overlapping were found to be the most frequent reasons for the defective characteristic of our study. Fishbone diagram is set up for both mismatching of triangular pockets and overlapping ratio because the reason causing them are dependent on each other's with also the defective reasons for bag valve width and the another side width.

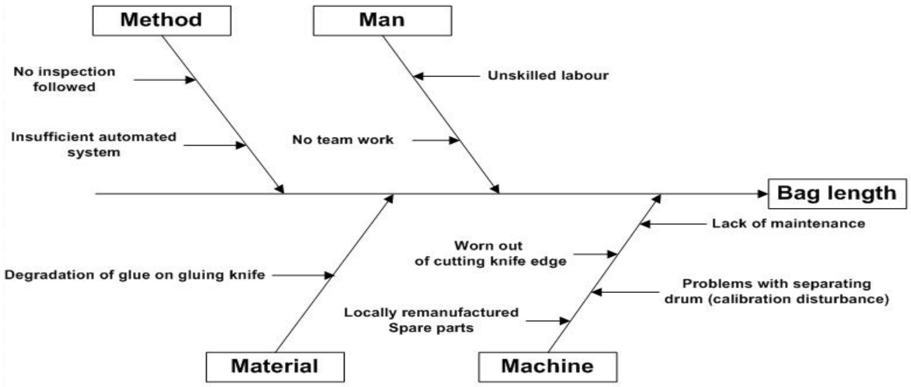

Figure 6 Fishbone diagram for the bag length

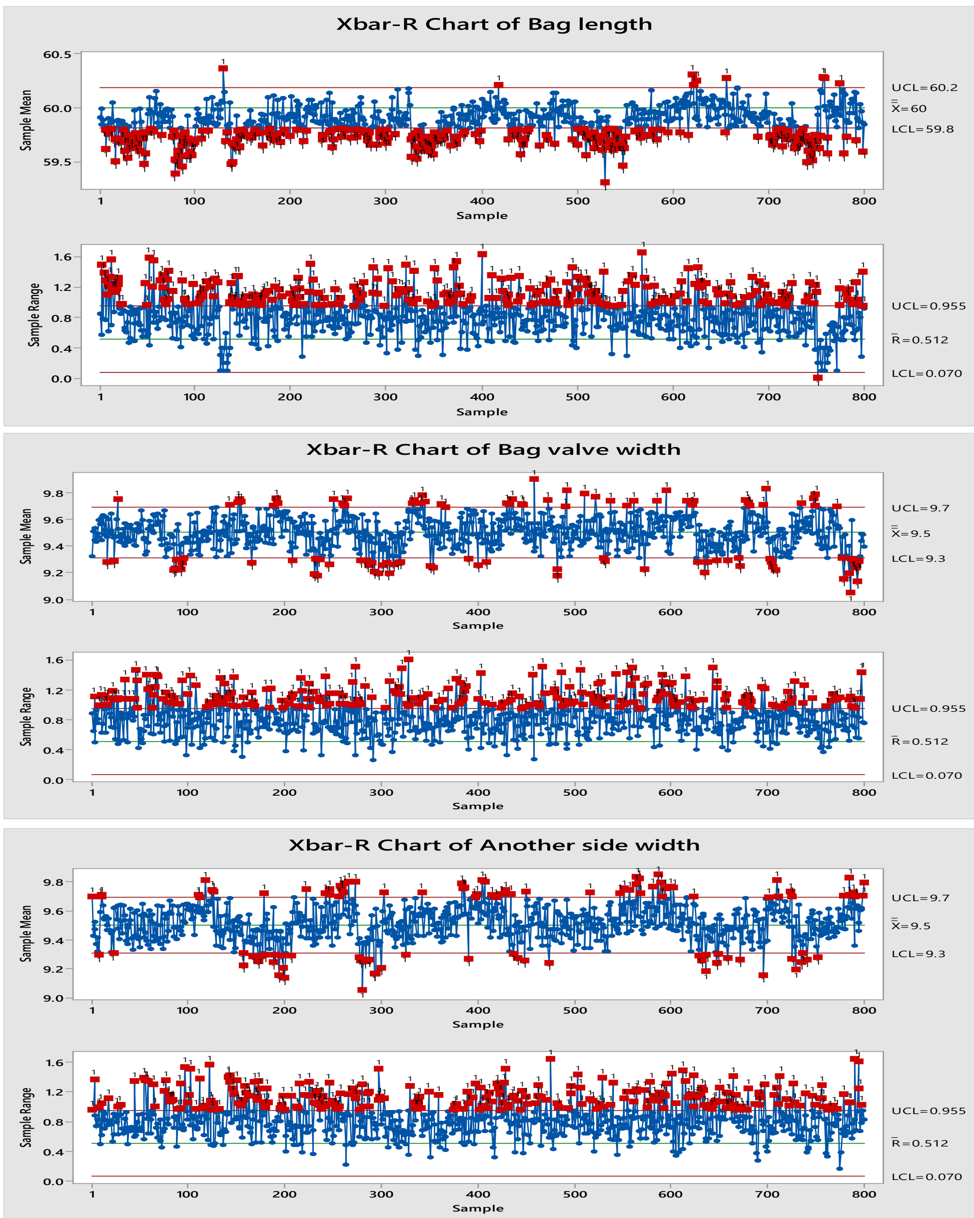

Figure 7 Xbar and R control charts for variable characteristics

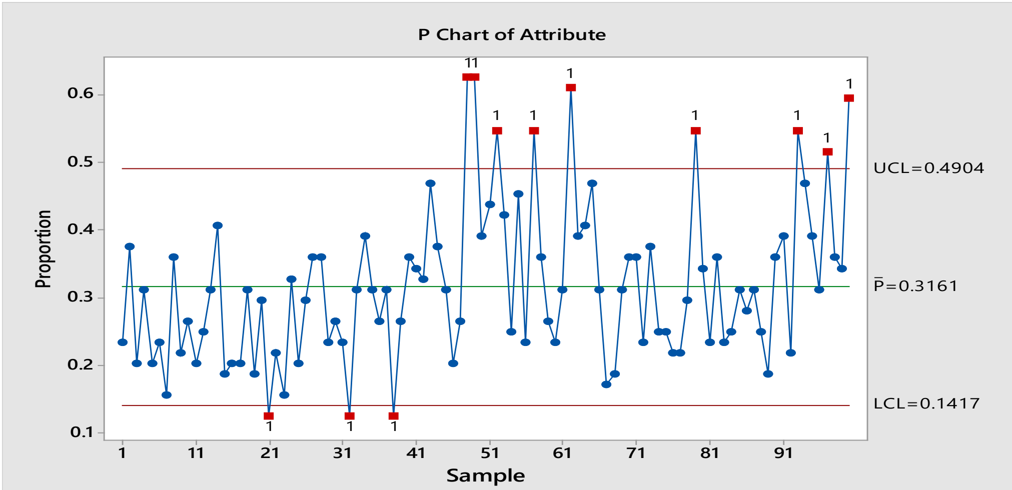

Figure 8 P control chart for attribute characteristics

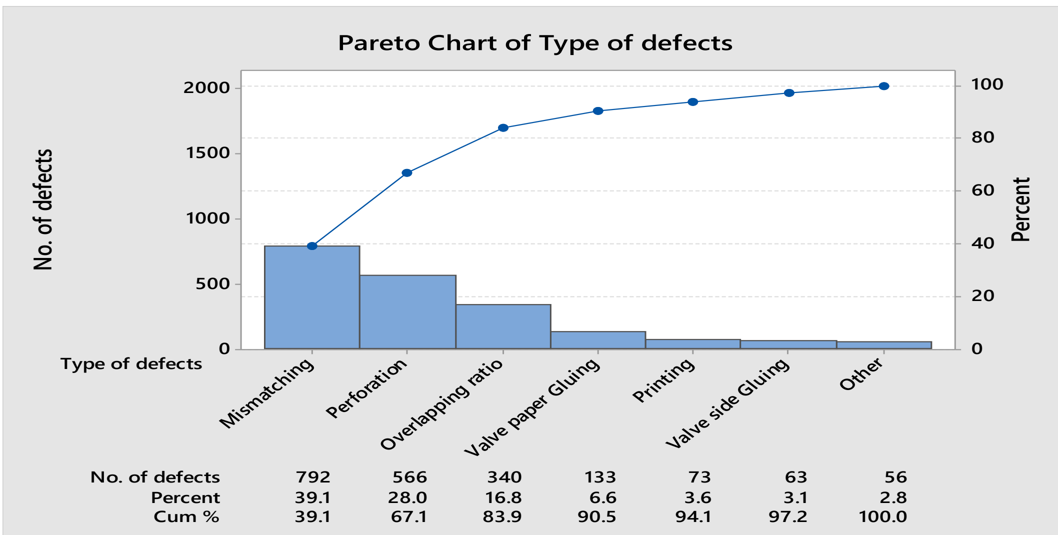

Figure 9 Pareto diagram analysis for attribute characteristics

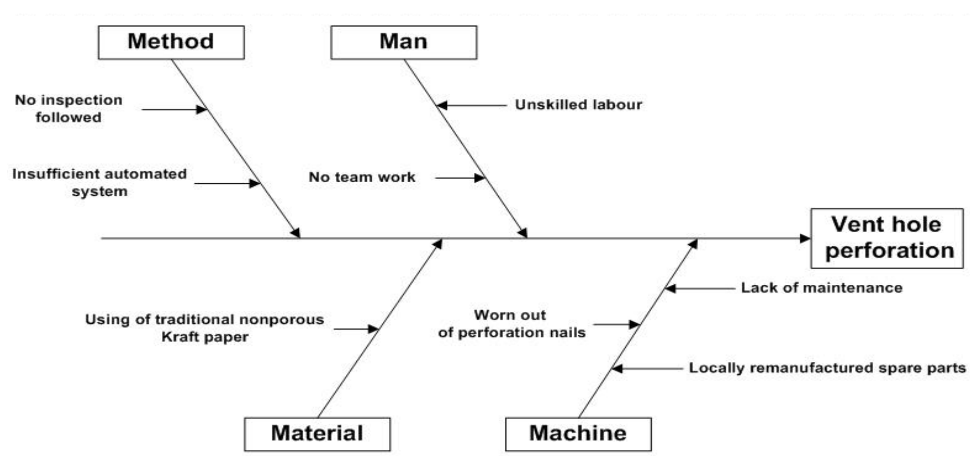

Figure 10 Fishbone diagram for vent hole perforation

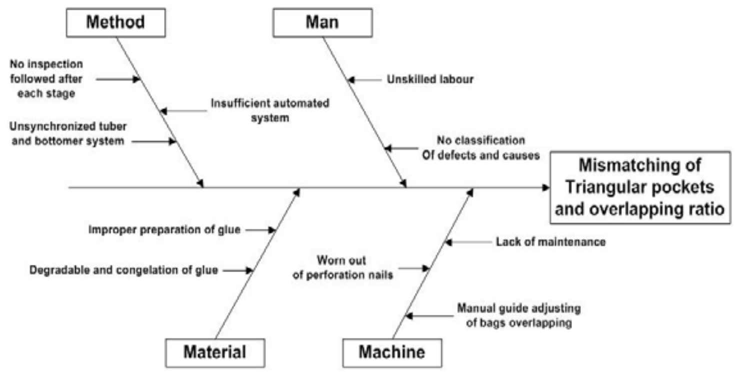

Figure 11 Fishbone diagram for mismatching of triangular pockets and overlapping ratio

5. Insights and recommendations

Some remedies are proposed and the condition for limited budget is taken into consideration. Inspection of every supplied material and remanufactured spare parts should be performed. It's preferable to buy the spare parts from well-known vendors. The company should carry on a quality control training program to make all staff familiar with SPC techniques. The company should specify a quality staff responsible for product inspection in each stage of production process and reporting the quality management with up-to-date. Elimination of kraft paper hole perforation process and purchasing porous kraft paper. Buying readily mixed glue that can last for a long time without degradation instead of preparing it with improper mix. Applying a daily machine maintenance checksheet, where the machine is checked regularly every shift to ensure that everything going right and record any notes to avoid machine problem increment. Constructing control chart in each stage of production process, not only to prevent defects but also to detect them and classification of defects, and causes.

6. Conclusion

From the case study results, we can conclude that the company is facing common quality problem related to the production process, in which the company should take actions to reduce these large number of defective bags and to avoid bigger loss. The results presented that small and medium companies can use SPC tools to solve such kind of quality issues of their products and services.

Finally, the problems of high defective bags ratio were tackled using SPC techniques which led to highlighting five contributions to rejection which are bag dimensions, vent hole perforation, mismatching of triangular pockets and overlapping ratio with defective ratio of 56%.

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