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Developing Control Charts in a Manufacturing Industry and Improvement of Quality Using PDCA Cycle

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Abstract

This paper presented the application of several statistical quality control tools. Using those, continuous quality improvement can be achieved. The control tools used were variable control charts and attribute control charts. The process output of an RMG manufacturing factory was studied. Using "Minitab 17" the above-mentioned control charts were developed. The control charts were used to analyze the current process stability. After analyzing it, Deming's PDCA cycle was used to identify and select opportunities for improving quality control. The PDCA cycle was developed based on the current state of the process and rate of defective products. Management personnel were involved with the generation of PDCA cycle. It was found that the process was not stable during the study period. The model of the PDCA cycle contains proposal for further improvement of the process.

Keywords: Process control, Quality improvement, Control Charts, PDCA cycle

1. Introduction

Quality is a term used to define the desirable characteristics that a product or service should possess. Experts define quality in many ways. According to Juran, quality is meeting or exceeding the expectations of customers [1]. To make quality products, a manufacturing facility should have stable or repeatable process. In broad sense it means, the manufacturing process should be operated with little variability from the nominal target of the product's quality characteristics [2]. Statistical process control is a set of tools that can help to reduce variability and achieve a stable process. SPC uses statistical methods to monitor and control a process and ensures production of conforming products [3].

Variation can occur in any process. There are two types of variations. Common causes of variations and special causes of variation. The process is stable if only common causes of variation is presented in the process. Special causes of variation are large in magnitude. If they are present than the process will be certainly out of control. They are also called assignable causes [4].

Depending on the types of data, control charts can be either attribute control charts or variable control charts. Attribute data can be counted and does not contain fractions. Variable data can be measured on a continuous scale. Some examples of attribute control charts are: P chart, U chart, C chart. Some examples of variable control charts are: X chart, R chart, S chart [5].

PDCA (Plan-Do-Check-Act) is used for continuous process improvement. It is known as Shewhart's cycle or Deming's PDCA cycle. It is also known as the never-ending improvement cycle [2].

The occurrences of defects in the production floor reduces the productivity as resources are wasted. A process that is stable will make less defective products. The stability of any process can be checked with control charts. An out of control process generates more defective products. Reducing the variations in the process will help to make quality products. PDCA cycle can be used to identify problems and provide solutions that can make the process stable and produce less defective products.

2. Materials and Methodology

An RMG factory in Bangladesh was selected for collecting the data. Initially data was taken from 1st January to 30th March of 2017. Total working days were 74 days. U chart was generated as the attribute control chart. R chart and X chart were generated as the variable control chart.
The choice of control limit is a critical decision. If the control limit is not set right, two types of error may occur. Type I error which is concluding a process is not in control when it is in control. Another is type II error which is concluding that a process is in control when it actually is not. Setting the control limits three standard deviation from the mean will have the probability of 0.0026 of type I error to happen. The probability of a type II error to happen depends on the power of the test [3]. In this paper, a control limit of three standard deviation was chosen.

For generating the U chart, the sample size and no. of defective item on each day were observed. Calculating the proportion defects on each day for the 74 days, U chart was generated using Minitab-17 software.

For generating variable control chart some alternate approach had to be taken. Since the factory under study produces several types of clothing, one type of clothing "Polo T-shirt for men" was selected. The selected product had several dimensions to be fulfilled. The chest measurement of the selected product's "L" size was taken under consideration for the variable control chart. In this case, 6 observations were performed every day for 25 days.

After investigating the control charts, Deming's PDCA cycle was generated for continuous process improvement. Discussion and interview session with management personnel was done before generating the PDCA cycle.

3. Data Analysis

The variable control charts were generated first. The data collected are shown on the below table:

Table 1. Data for the variable control charts

Sample	Observation-1	Observation-2	Observation-3	Observation-4	Observation-5	Observation-6
1	54.95	54.26	55.76	54.80	53.94	54.38
2	54.61	55.28	53.80	54.53	54.40	54.93
3	53.79	54.72	53.52	55.36	55.49	54.13
4	55.10	53.39	54.23	53.58	53.83	55.84
5	54.59	53.97	53.35	54.35	53.50	55.83
6	55.37	54.21	53.66	54.14	53.59	54.48
7	54.39	54.24	54.20	54.67	55.83	53.60
8	55.88	55.07	55.24	55.04	54.93	53.95
9	54.41	53.72	54.64	54.26	55.49	55.60
10	55.77	54.10	53.78	54.17	53.68	55.75
11	53.91	55.62	55.40	54.63	55.68	55.38
12	53.53	55.58	55.35	55.22	53.96	55.11
13	53.90	54.03	54.07	53.87	53.58	54.61
14	53.66	53.56	53.66	53.68	54.93	53.43
15	55.39	54.32	53.44	54.75	54.27	53.37
16	55.48	54.12	55.53	55.04	54.48	55.46
17	55.06	55.73	54.92	55.24	53.69	55.52
18	54.96	55.29	54.44	55.28	54.16	54.54
19	54.80	54.39	54.81	53.65	55.36	53.95
20	53.42	53.62	54.34	53.89	55.59	54.92
21	54.02	53.79	54.76	54.91	55.20	55.13
22	53.54	54.04	54.89	55.61	54.05	54.52
23	55.45	54.19	55.59	53.69	53.42	55.39
24	53.40	53.81	54.18	54.44	54.05	55.55
25	54.86	53.48	55.18	53.46	53.70	54.36

The Xbar chart and R chart were generated using Minitab-17. The variable control charts are shown in figure 1:

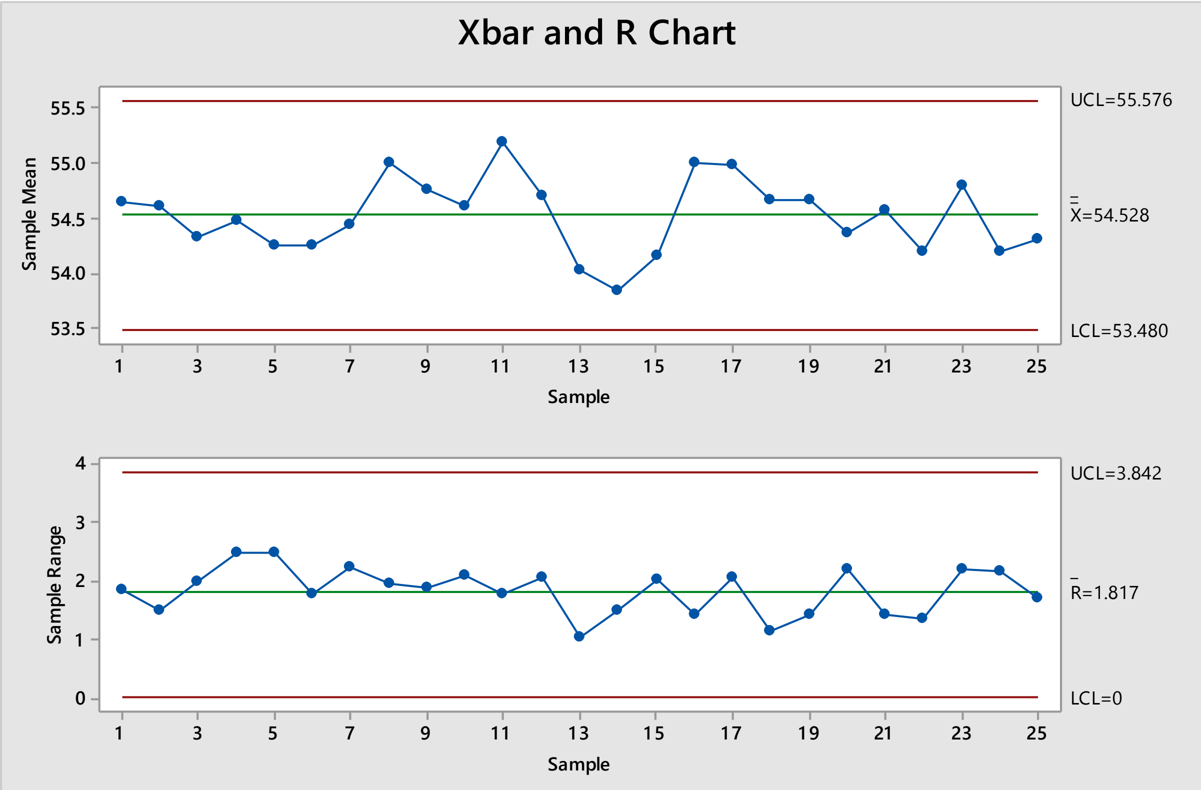

Fig.1. Xbar and R chart for the selected product.

The centerline for the Xbar chart was determined by the following equation [4]:

$$\bar{\bar{X}} = \frac{\sum x}{n} \tag{1}$$

Control limits were set ±3σ from the centerline. The equation for upper control limit and lower limit are [4]:

$$UCL = \bar{\bar{X}} + A_2\bar{R} \tag{2}$$

$$LCL = \bar{\bar{X}} - A_2\bar{R} \tag{3}$$

For R chart, the control limits were determined using the following equations [4]:

$$\bar{R} = \frac{\sum_{i=1}^{n} R_i}{n} \tag{4}$$

$$UCL = \bar{R}D_3 \tag{5}$$

$$LCL = \bar{R}D_4 \tag{6}$$

The values of the constant A_2, D_3 and D_4 can be obtained from standard statistical table [2].
From the graph above it can be concluded that X-bar chart and R chart both are in control limit.

For attribute control chart, U chart will be generated. The control limits of U chart were determined using the following equations [5]:

$$\bar{u} = \frac{c}{n} \tag{7}$$

$$UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}} \tag{8}$$

$$LCL = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}} \tag{9}$$

Where, c = no. of defects, n = total sample checked.

The data collected from the selected factory was for 74 days. In the span of 3 months, total products checked 155,571. Total defective products 21,877. Data for the first 5 days are shown in table 2:

Table 2. Data of the first 5 days for U chart

Checked	Defects	Proportion Defects
2575	247	0.09592233
2205	282	0.127891156
2017	213	0.10560238
1832	317	0.173034934
1847	367	0.198700596

Based on all the data of the 74 days, the U chart drawn is showed below in figure 2:

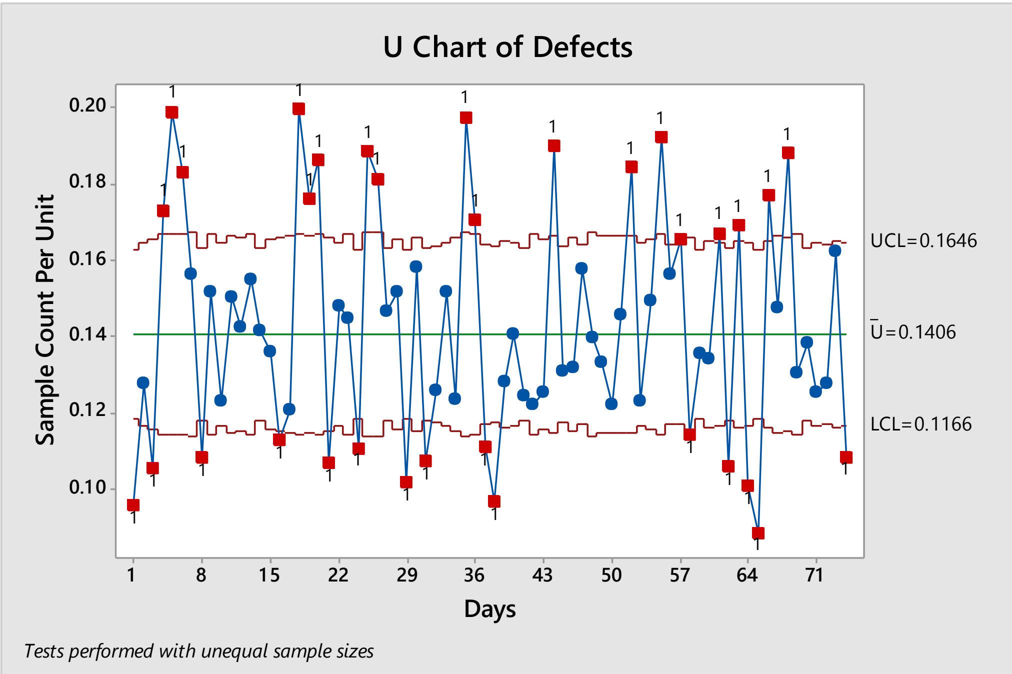

Fig. 2. U chart for defects of the 74 working days.

From 74 data points, 33 of them are out of the control limits. It is necessary to improve the process. For continuous process improvement, Deming's PDCA cycle can be used.

4. Reducing Defects Using PDCA Cycle

Based on the data, observation and consultation with management personnel, a model of PDCA cycle for the selected factory was generated. The PDCA cycle is discussed below:

a. Plan

This is the first phase of the cycle. In this stage, a proposal was submitted for improvement of the process. Before submitting the proposal, major defects that occurred in the 3 months study span were identified. The number of occurrences of each defect were noted by the quality control inspectors. The major defects were:

i. Dirty spot (35.34%)
   Major causes: unclean work area, careless ness of operators and mishandling.
ii. Open seam (16.23%)
   Major causes: fabric rolled out, incorrect method and wrong needle angle.
iii. Oil spot (12.57%)
   Major causes: dirty machines and unclean workstation.
iv. Raw edge out (10.91%)
   Major causes: tension in the fabric and rolled fabric.
v. Point up down (3.7%)
   Major causes: operator's inefficiency.

There were other types of defects too. However, these 5 defects sum up to most of the total defects. As a result, for this study only these defects were kept under consideration. Being able to reduce these effects will reduce the no. of nonconforming items and will make the process more stable. It is not possible to change everything overnight. So, the idea that was suggested was to reduce these defects one by one. Among the 5 major problems, dirty spot had the highest percentage of occurrences. The plan that was proposed was to implement 5s or Japanese housekeeping technique and revise again to see the variation in the process.

b. Do

This is the second phase of the cycle. It is also known as implement. In this phase, the planning should be carried out on a small or pilot scale first. As it was proposed to apply 5s, the first step should be informing the employees about 5s. Introducing the employees with the idea of 5s would make it easier to implement it. The summary of the steps that should be followed are:

Table 3. Implementing 5s

Name of the Step	Activities under it
1. Sort	a. Remove unnecessary items b. Tag everything that is not needed in the workstation. c. Discard the items in a holding area.
2. Set in order	a. Locate the necessary items in their proper place. b. Use marker, labels, paint to make the position of any item clear for everyone around the workstation.
3. Shine	a. Clean the workstation daily. b. Daily inspection should be arranged to enforce the cleaning process.
4. Standardize	a. Routine inspection should be done to check the first 3 steps are running properly. b. All the three steps before it should be standardize using written notice and memo to both the management personnel and the employees.
5. Sustain	a. Commitment from each employee is needed to achieve this. b. Periodic review of the 5s process should be done.

c. Check

After implementing the 5s process as proposed in the planning phase, new control charts should be developed using new data. The control chart will show how much change was done in the process variation after implementing 5s.

d. Act

Based on the analysis of the new data either the management will adopt the proposed plan or a new set of plans should be proposed. After implementing 5s, if the process shows more stability than before and produces less defects than 5s process should be implied as a part of operation. Implementing 5s alone cannot make a lot of changes. For making the process completely stable, more PDCA cycle session had to be done with newer proposal to reduce defects.

5. Discussion

Using the control charts, it was found that the process was unstable. In the 3 months study period, the process generated 14.06% defective products. In other words, 14 out of every 100 customers were dissatisfied. The objective of any organization should be full customer satisfaction. The defect rate of this factory is very high. Defectives products cannot be sold in the market. They are simply wastes and causes to reduce profits. To make the process stable and produce less defective products, a PDCA cycle model was generated. The study of this paper can be continued further in the future by following the results from the implementation of the PDCA cycle. In this study, only the sewing section of a garments factory was considered. Other sections like dyeing, cutting, finishing and packaging were not considered. To improve the quality, the other sections should be studied as well.

6. Conclusion

The control chart serves the purpose to show if a process is stable or not. A stable process will produce defect free products. As defects are wastes, a stable process will increase sales and profitability. To gain customer satisfaction it is necessary to produce products with no defects. A stable process and defect free products are good for the company's sustainability in the long run. Deming's PDCA cycle can help to improve the process continuously. As it is a never-ending cycle, the problems that are occurred will be diminished if this cycle is properly implemented.

7. References

[1] J.M. Juran, "Quality-control handbook", *Mcgraw-Hill*, 4th edition, 1988.

[2] I. Madanhire, C. Mbohwa, (2015). "Application of Statistical Process Control (SPC) in Manufacturing Industry in a Developing Country", *Procedia CIRP*, Vol. 40, pp. 580-583, 2016.

[3] A. Mitra, "Fundamentals of Quality Control and Improvement", *Wiley*, 3rd edition, 2008.

[4] D. C. Montgomery, "Introduction to Statistical Quality Control", *Wiley*, 7th edition, 2009.

[5] J. S. Oakland, "Statistical Process Control", *Butterworth-Heinemann*, 5th edition, 2003.