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ASSESSMENT OF THE PROCESS STABILITY OF COTTON YARN COUNT BY MEANS OF VARIABLE AND ATTRIBUTE CONTROL CHART ON A SPINNING MILL

J. HOSSEN AND S.K. SAHA

Department of Textile Engineering, Ahsanullah University of Science and Technology, 141-142 Love Road, Tejgaon I/A, Dhaka 1208. Bangladesh.

Corresponding author & address: Jamal Hossen, E-mail: jamalsqr@yahoo.com
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ABSTRACT

Hossen J, Saha DSK (2012) Assessment of the process stability of cotton yarn count by means of variable and attribute control chart on a spinning mill. *J. Innov. Dev. Strategy.* 6(1), 32-39.

A production process is said to be in control when the quality characteristics of a product are subjected only to random variation (or common cause variation) that is variation in process performance due to normal or inherent interaction process components (people, machine, material, environment, and methods). Whenever variable data are used, a combination of two charts, chart monitoring the mean and chart monitoring the spread are used, and usually single chart is used for attribute data. Specification limits are based on product or customer requirements. If all the data points are within the control limits, be sure to check the other signals that indicate special cause of variation. This paper provides an analytical study of statistical process control of yarn count by 3σ control charts of variable and attributes control charts which are commonly used.

Key words: *Yarn count, variable control chart, attribute control chart, $\bar{\bar{X}}$-S chart, p chart, carding, neps removal efficie*

INTRODUCTION

Control chart is the seventh tool of total quality management. Possibly, this is the most popular and widely used statistical tool in quality control. In 1924 Walter Shewhart of Bell Laboratory introduced the concept of "Control Chart" as a tool for verifying level of variation and trend in quality characteristics (Hasin 2007). The purpose of a control chart is to detect any unwanted changes in any process. They indicate to the workers, group leaders, quality control engineers, production supervisors and management whether the production of the part or service is "in control" or "out of control". When used control charts and practiced correctly, it provides a clear picture of the process performance that will help the process owner to react accordingly to the variation being communicated by the control charts (Bodino and Reyes, 2007).

There are two types of control chart. A variable control chart requires the interval or the ratio scale of measurement. An attribute control chart classifies a product or service as either acceptable or unacceptable. It is based on the nominal scale of measurement (Lind *et al.* 2007-2008). Commonly used variable control charts are $\bar{\bar{X}}$-R chart, $\bar{\bar{X}}$-S chart, moving range (MR) chart, cumulative sum (CUSUM) chart, exponentially weighted moving average (EWMA) chart. The most commonly used attribute control chart are p chart (Proportion non-conforming), np chart (Number non-conforming), c chart (count chart), u chart (Hasin 2007).

Control charts are not based on the assumption that the process data are normally distributed, but the criteria used in the tests for special causes are based on this assumption. If the data are severely skewed, or if the data fall too heavily at the ends of the distribution ("heavy-tailed"), the test results may not be accurate. For example, the chart may signal false alarms at a higher rate than expected (Minitab® 16, Statistical software).

This study describes an approach using basic control charts that can help improve data quality, which adds value to a data base. Single yarns of six different counts (English Ne) were produced on a textile spinning mill which were pre-fixed by drafting in ring spinning machine. Six different counts of thirty different days at hundred percent knitted cotton yarns were analyzed graphically, variation in output quality characteristics against prefix upper and lower limits.

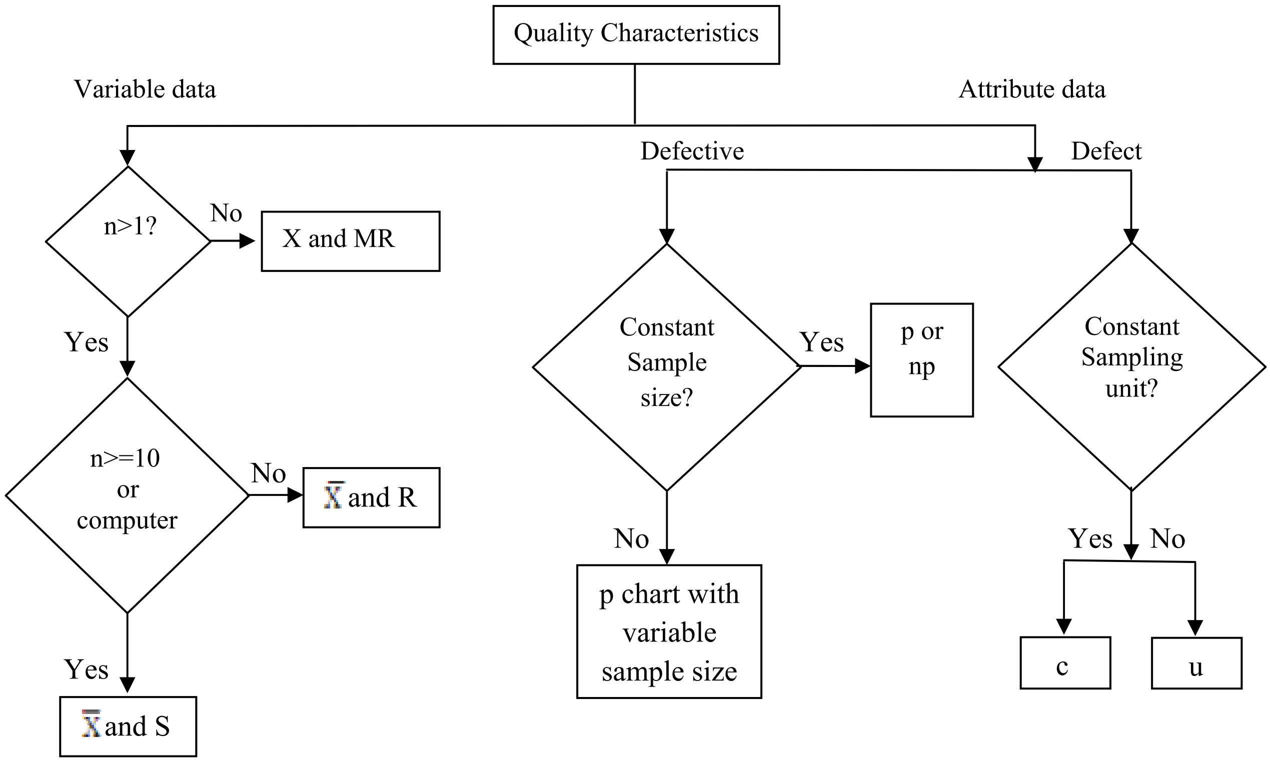
P chart (fraction non-conforming)

Although a common practice is to use percentage non-conforming, or fraction rejected chart, the complementary value, i.e. fraction conforming chart will also carry the same message. This is known as control chart on process yield (Hasin 2007).

Since only two outcomes possible, successive events are independent and distribution assumes a constant probability of occurrence of the event under consideration (i.e. the rejection of an item), the statistical basis of the p chart is the binomial distribution. However, if the production takes place in lots/batches in bundles, rejections or acceptance may also occur in bundles/batches. In such a case, independence of successive events and constant probability of occurrence do not apply. As a result, the binomial distribution would be inappropriate, although in majority of common situations; rejection takes place in singular, thus validating use of binomial distribution (Hasin 2007).

A common problem in statistics is the availability of population standard deviation (σ) and mean (μ) values. In case of p chart, it is about knowing p value. Two situations arise here- whether population fraction non-conforming p is known or unknown. The purpose of p chart is to detect if the process has improved beyond historical levels.

Control chart selection



MATERIALS AND METHODS

In this study six different counts, (30/1 Ne and 26/1 Ne combed knitted, 34/1 Ne, 30/1 Ne, 24/1 Ne and 20/1 Ne carded knitted yarn) and also six machines for each count of yarn, which were being produced yarn on the spinning mill (for thirty days long from the roving hank 0.80). Then yarn counts were calculated by wrap reel and Uster Auto Sorter. The tests were continued for 30 days of fixed ten spindle number. For each day sixty results were obtained for six different counts. In case of combed and carded yarn, twist multiplier were 3.5 and 3.6 respectively. Then $\bar{X}$- S chart for six different counts of yarn and p chart (fraction non-conforming) for overall 1800 data of 30 days were established.

The sample size is 10 for each count (where n =10) and also sample size is constant for different counts. So $\bar{X}$ – S chart and p chart were selected as variable and attribute control chart.

Letting $x_1, \ldots, x_n$ represent a subgroup of n observations, traditional Shewhart control charts monitor process location and process variability by tracking $\bar{x}$ and the range (R) (or standard deviation (S)) at each subgroup. The control limits for the subgroup means (i.e.,$\bar{x}$'s) are of the form $\bar{\bar{X}} \pm A_3 \bar{S}$ where A_3 is statistically determined constant, $\bar{\bar{X}} = k^{-1}\sum_{j=1}^{k} \bar{x}_j$ is the mean of the k subgroup means, $\bar{S} = k^{-1}\sum_{j=1}^{k} S_j$ is the mean of the k subgroup ranges and standard deviations respectively. The control limits associated with the subgroup range and the subgroup standard deviation are of the form $B_3 \bar{S}$ and $B_4 \bar{S}$ respectively where B_3 and B_4 are also statistically determined constants (Spring and Cheng, 1998).

For the $\bar{X}$ chart, the upper (UCL) and lower (LCL) control limits as well as the centerline (CL) are then calculated by the following:

$$UCL_{\bar{x}} = \bar{\bar{X}} + 3\sigma_x \quad \bar{\bar{X}} + A_3\bar{S}$$
$$CL_{\bar{x}} = \bar{\bar{X}}$$
$$LCL_{\bar{x}} = \bar{\bar{X}} - 3\sigma_x \quad \bar{\bar{X}} - A_3\bar{S}$$

For the S chart, the control limits are calculated by the following:

$$UCL_s = \bar{S} + 3\sigma_s \quad B_4\bar{S}$$
$$CL_{\bar{s}} = \bar{S}$$
$$LCL_s = \bar{S} - 3\sigma_s \quad B_3\bar{S}$$

Where, A_3, B_3 and B_4 are all constants which can be found from table of control charts factor.

For the 3σ control chart the equation for p chart stands as follows when p is known:

$$UCL_p = p + 3\sqrt{\frac{p(1-p)}{n}}$$

$$CL_p = p$$

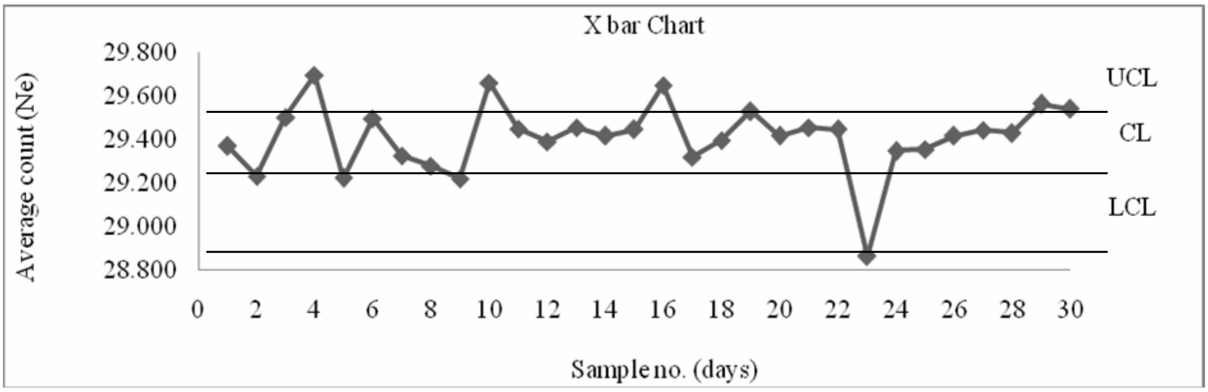
$$UCL_p = p - 3\sqrt{\frac{p(1-p)}{n}}$$

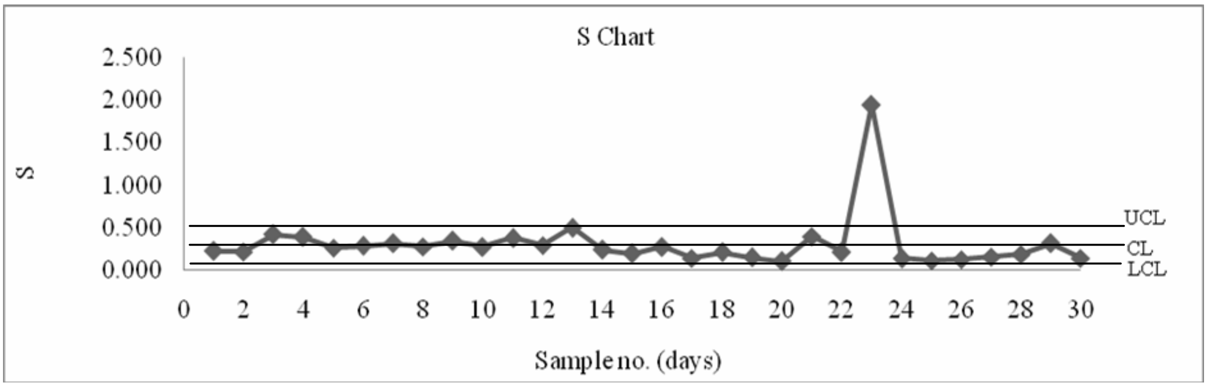
ESTABLISHMENT OF $\bar{X}$ - S CHART AND P CHART AND DISCUSSION

***$\bar{X}$* - S Chart for 30/1 Ne combed knitted yarn**

Table 1

Chart Name	UCL	CL	LCL
$\bar{X}$	29.706	29.410	29.114
S	0.522	0.304	0.086



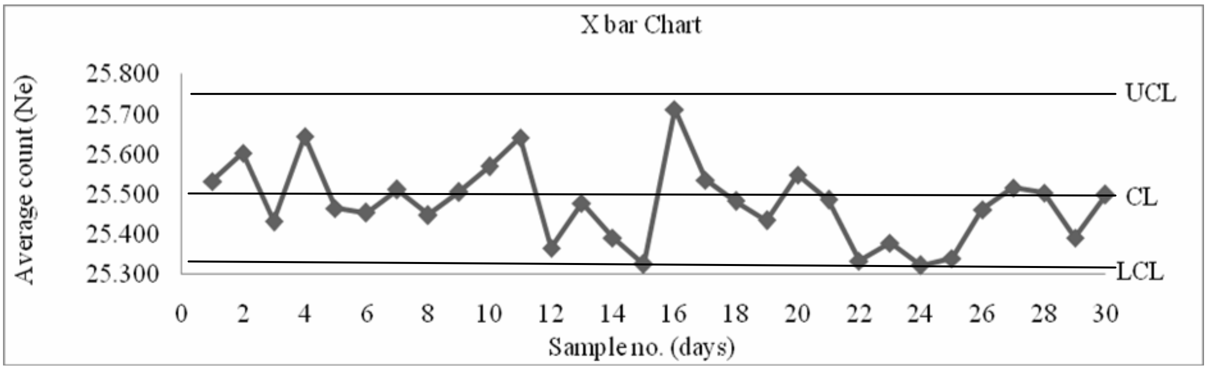


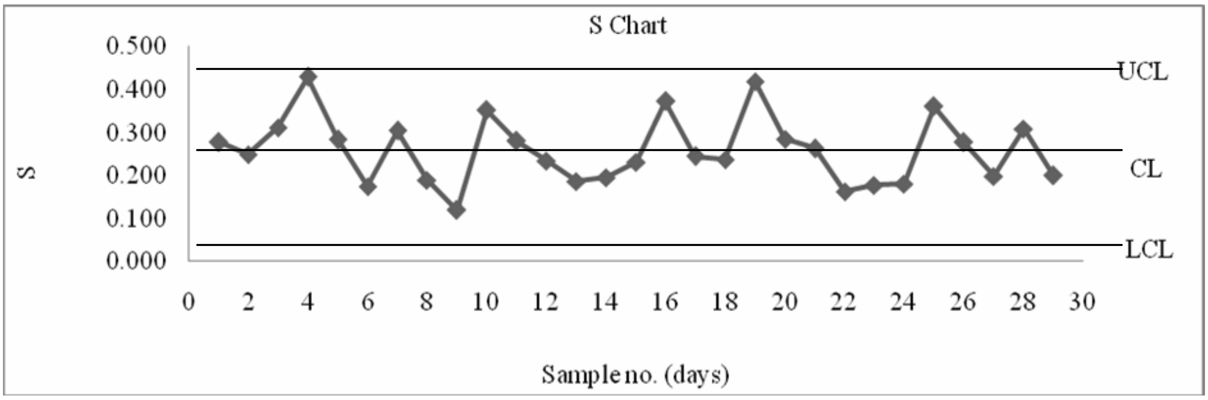
The $\bar{X}$ and S charts above are not in statistical control. This means that the process is inconsistent and not predictable. The average and standard deviation of sample number 23 is out of control. The average standard deviation will be 0.304 but it can vary anywhere from 0.086 to 0.522. The long-term average count will be 29.410. The average will vary from 29.114 to 29.706. An adjustment in the process is necessary.

***$\bar{X}$* - S chart for 26/1 Ne combed knitted yarn**

Table 2

Chart Name	UCL	CL	LCL
$\bar{X}$	25.736	25.480	25.224
S	0.451	0.263	0.075



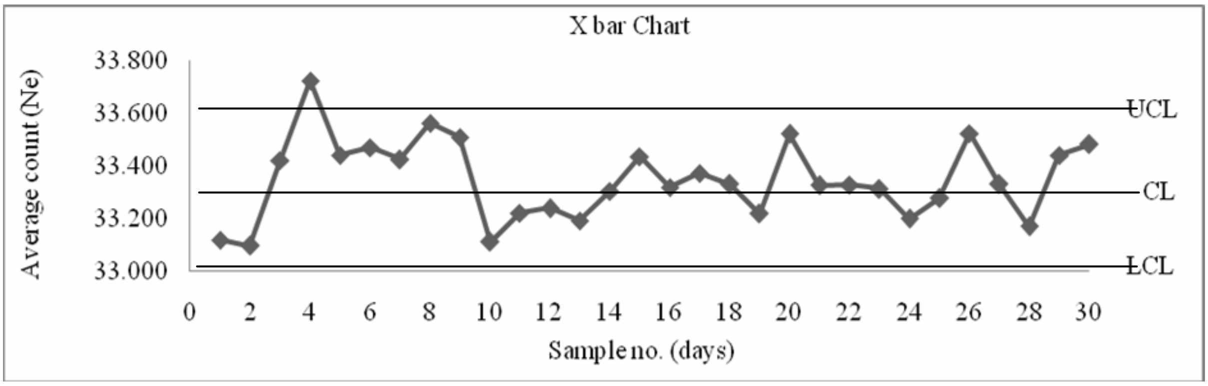


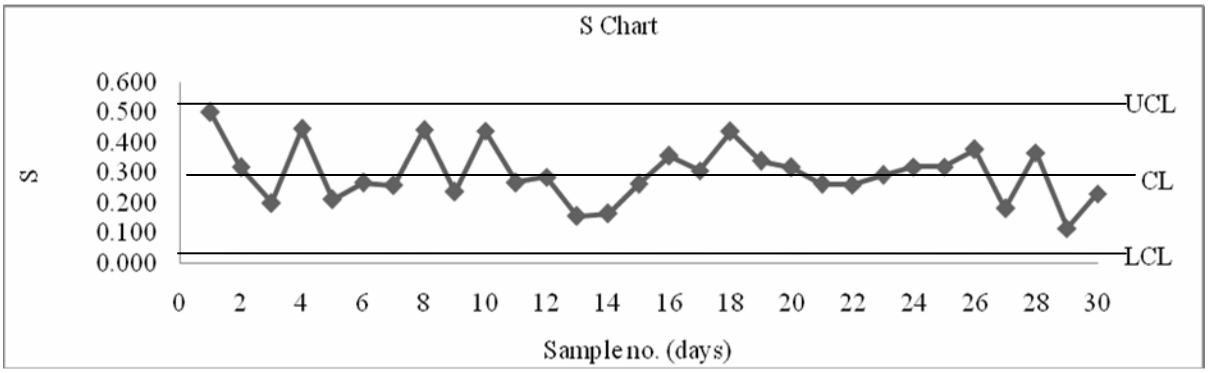
The $\bar{X}$ and S charts above are in statistical control. This means that the process is consistent and predictable. There are only common causes of variation present. It means that variation within the subgroup is consistent from subgroup to subgroup. There is no statistical difference between these standard deviations. The average standard deviation will be 0.263 but it can vary anywhere from 0.075 to 0.451. The long-term average count will be 25.480. The average will vary from 25.224to 25.736.

***$\bar{X}$* - S chart for 34/1 Ne carded knitted yarn**

Table 3

Chart Name	UCL	CL	LCL
$\bar{X}$	33.639	33.349	33.060
S	0.510	0.297	0.084



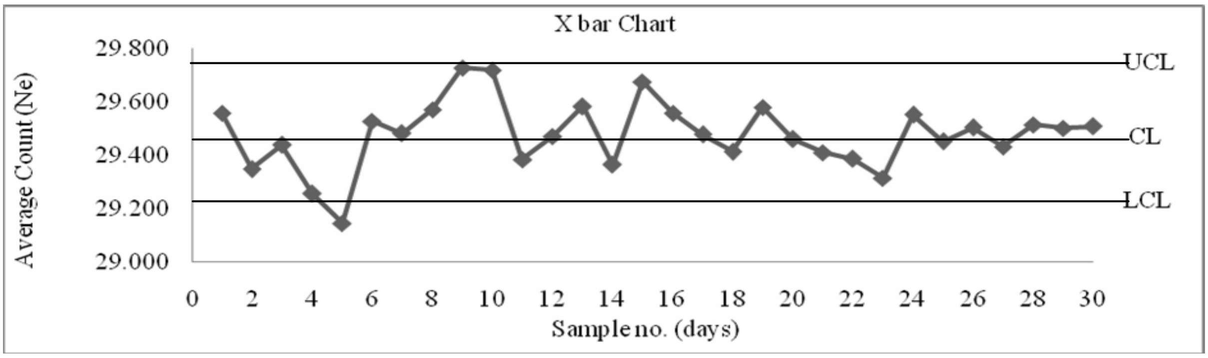


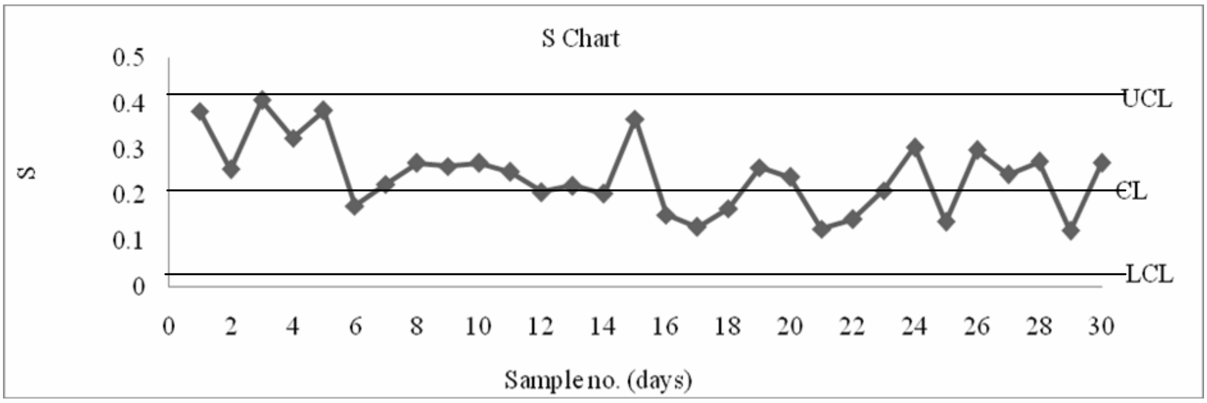
From the above charts it is seen that there is no statistical difference between these standard deviations. The average standard deviation will be 0.297 but it can vary anywhere from 0.084 to 0.510. The average count of sample number 4 is out of control. The long-term average count will be 33.349. The average will vary from 33.060 to 33.639. So the process is out of control and special cause of variation is present.

***$\bar{X}$* - S chart for 30/1 Ne carded knitted yarn**

Table 4

Chart Name	UCL	CL	LCL
$\bar{X}$	29.716	29.478	29.240
S	0.419	0.244	0.069



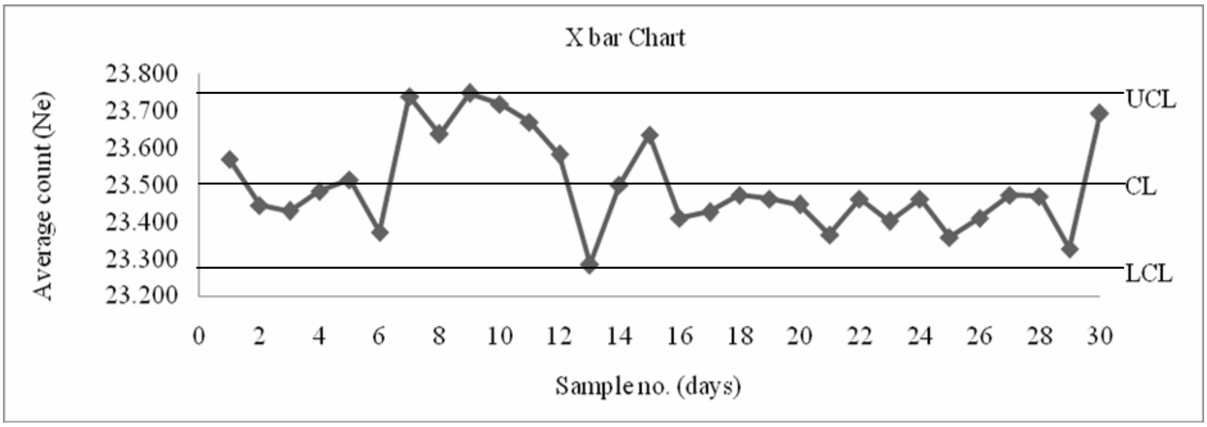


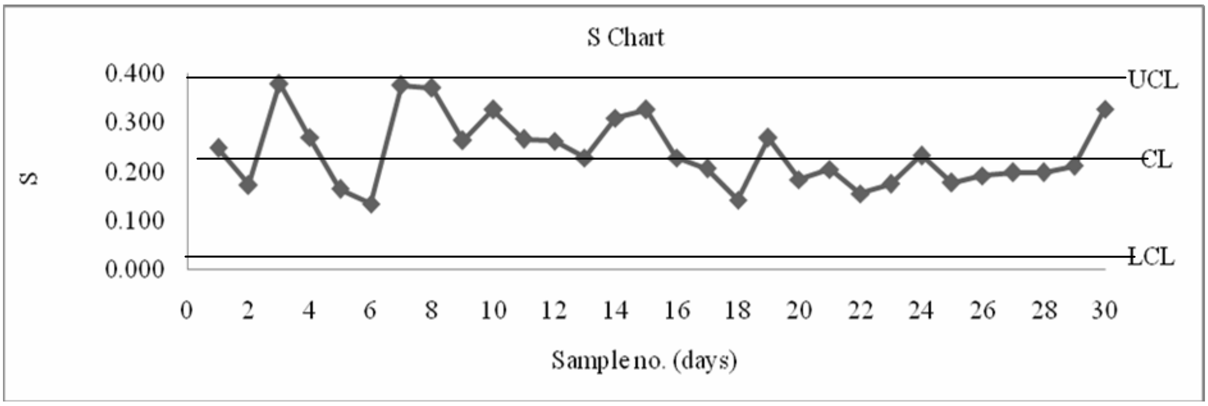
From the above graph we can see that there is no statistical difference between these standard deviations. The average standard deviation will be 0.244 but it can vary anywhere from 0.069 to 0.419. The average count of sample number 5 is out of control. The long-term average count will be 29.478. The average will vary from 29.240 to 29.716. So special cause of variation is present here and process is not under controlled.

***$\bar{X}$* - S chart for 24/1 Ne carded knitted yarn**

Table 5

Chart Name	UCL	CL	LCL
$\bar{X}$	23.734	23.499	23.264
S	0.414	0.241	0.068



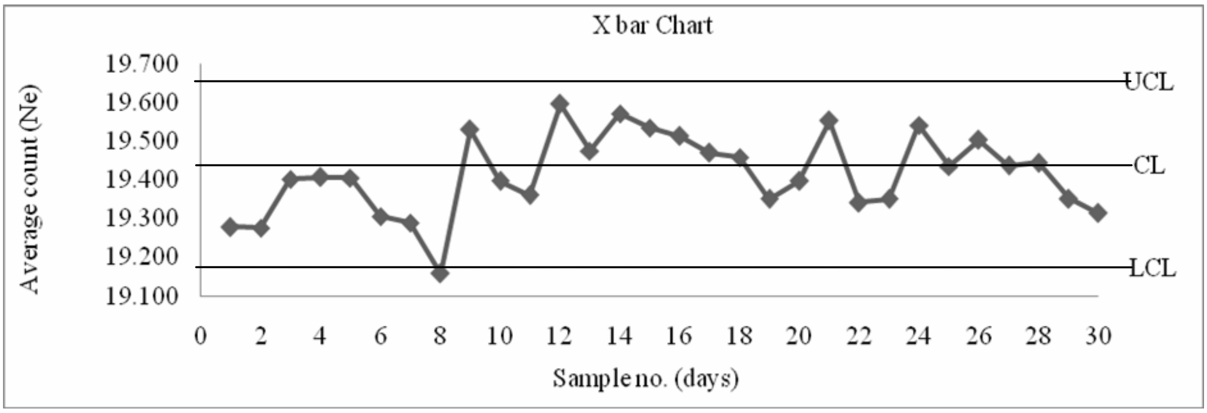


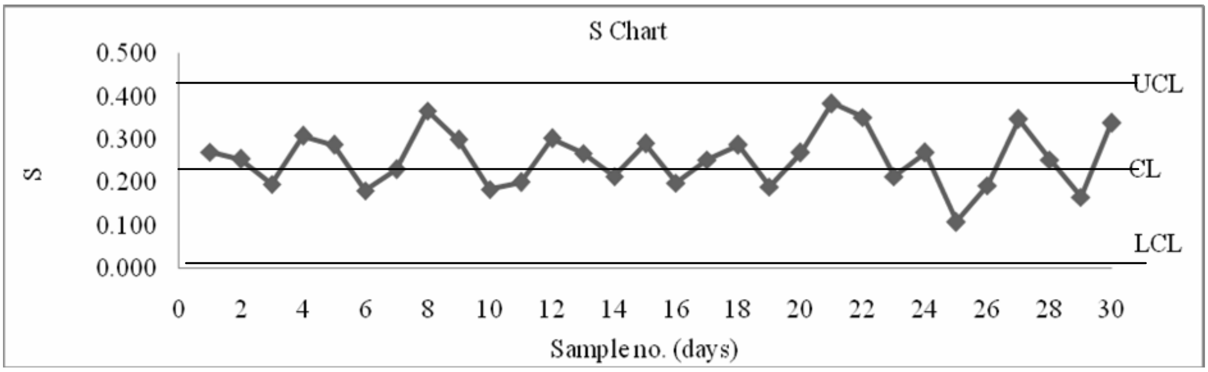
The S chart above is in statistical control. The average standard deviation will be 0.241 but it can vary anywhere from 0.068 to 0.414. The average count of sample number 7, 9 and 10 are out of control**.** The long-term average count will be 23.499. The average will vary from 23.264 to 23.734. Due to special cause of variation the process is out of control.

$\bar{X}$ - S chart for 20/1 Ne carded knitted yarn

Table 6

Chart Name	UCL	CL	LCL
$\bar{X}$	19.665	19.415	19.165
S	0.439	0.241	0.073





From the above charts it is seen that there is no statistical difference between these standard deviations. The average standard deviation will be 0.241 but it can vary anywhere from 0.073 to 0.439.The average count of sample number 8 is out of control. The long-term average count will be 33.349. The average will vary from 19.165 to 19.665. So the process is out of control.

From the above graph we can see that all of data are between UCL and LCL and other data are not properly distributed. So process is under controlled. From the above chart we can see that the process is in control on an aggregate basis, although certain points indicate slight instability in the process. Nevertheless, the process is fairly random around the mean. It is, thus, conclude the trial control limits can be adopted for future time period.

Table 7. Number and fraction defective (non-conforming)

Sample No. (i)	No. of failure (di)	Fraction non conforming	Sample No. (i)	No. of failure (di)	Fraction non conforming
1	7	0.12	16	3	0.05
2	6	0.10	17	3	0.05
3	4	0.07	18	3	0.05
4	7	0.12	19	0	0.00
5	6	0.10	20	4	0.07
6	1	0.02	21	3	0.05
7	6	0.10	22	3	0.05
8	8	0.13	23	4	0.07
9	5	0.08	24	2	0.03
10	9	0.15	25	2	0.03
11	5	0.08	26	1	0.02
12	6	0.10	27	2	0.03
13	4	0.07	28	4	0.07
14	2	0.03	29	2	0.03
15	4	0.07	30	3	0.05
			Total	119	1.98

P chart for data set of table A

$$UCL_p = 0.066 + 3\sqrt{\frac{0.066 \times 0.934}{60}} = 0.207$$

$$CL_p = 0.066$$

$$LCL_p = 0.066 - 3\sqrt{\frac{0.066 \times 0.934}{60}} = -0.019 = 0$$

$$P = \frac{1.98}{30} = 0.066$$

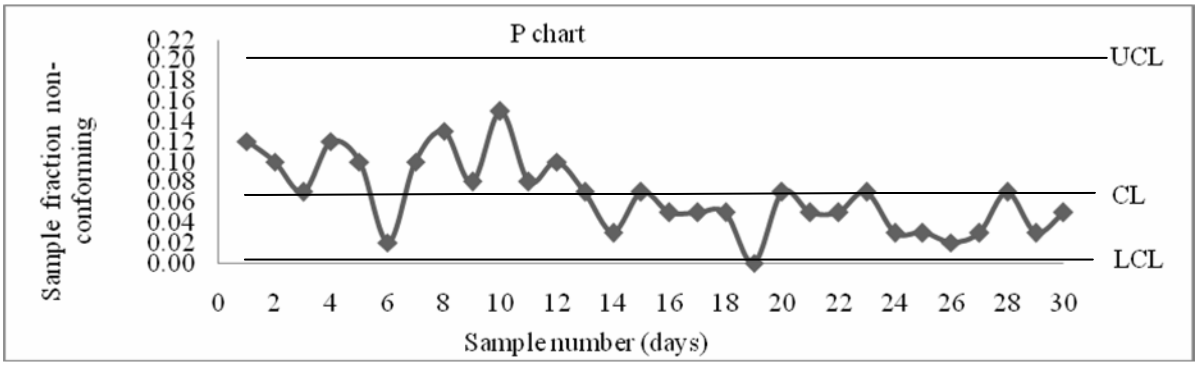


Figure. P chart for data set of table 7

The first eight points are plotted and a downward and upward trend can be noticed. The other points are really randomly plotted. If any sample number fall outside the upper or lower control limit than that sample should be dropped from the data and new trial limit can be computed. The LCL is a negative value, which is infeasible, because fraction non-conforming (or number of non-conforming units) can not be negative, thereby justifying to be taken as zero. The process is in statistical control. This means that the process is consistent and predictable. On average, each day will have about 6.6% of the counts with errors. Some days it may be as high as 15% or as low as 0.0%. Only common causes of variation are present. Note that this does not mean that the process is acceptable. Having 6.6% of invoices with errors is not acceptable. The next step is to apply a problem-solving model to reduce the number of errors. One should be using a Pareto diagram with this p control chart. The Pareto diagram is used to determine the reason for errors and the frequency with which they occur.

CONCLUSION

In this article, a statistical process control charting exercise was proposed that allows the quality control department to examine the process performance over time. Control charts are very effective way to judge the process stability. If they indicate that the process is in statistical control, extend the control limits into the future and monitor the process performance using these control limits. If the control charts indicate that there are special causes of variation, find the reason for the special cause of variation and remove it from the process. One has 30 points in a row in statistical control, recalculate the control limits based on that data, and use those limits in the future. Any spinning mill can examine the process stability (carding neps removal efficiency, drawn sliver weight and roving hank) by using the control charts used in this study.

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