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Research Article

Monitoring Yarn Count Quality using Xbar-R and Xbar-S Control Charts

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Abstract: Yarn quality monitoring is necessary by the spinners to sustain their business in the world market. Therefore, yarn quality control is a basic protocol requirement for producing good quality textile products. For this purpose, quality control charts are used for monitoring yarn quality at each step during the yarn manufacturing process. In this study, we considered Ring and Auto Cone departments and tested/monitored the yarn count quality by using Xbar-R and Xbar-S control charts in both departments. Machine-wise yarn count samples were selected to monitor the yarn count quality in both departments. It was observed that in Ring department yarn count quality was not in statistical control. However, in auto cone department; yarn count quality was in statistical control. So control charts are a good tool for monitoring the yarn count quality.

Keywords: Autocone, ring frame, yarn count, process monitoring

1. INTRODUCTION

In world's competitive business environment, billions of dollars are spent annually for quality improvement. Intense global competition and other factors are encouraging the manufacturers to produce good quality products in various fields, i.e., health, medicine, textile, food, etc. [1]. World fiber production was predicted 33 million tons for the year 2013 [2]. In textile industry, for ensuring product quality, adherence to process control is mandatory [3]. In fact, adoption of quality control in textile industry in China can be traced back to the Zhou Dynasty during 11th to 8th centuries B.C. At that time, quality of cotton and silk products was not up to standard requirements of market [4-5]. First ever time, Statistical Quality Control (SQC) was applied in the yarn manufacturing industry during late 1940s to 1950 [4]. In 1981, Milliken & Company (Textile Company) applied a total quality management (TQM) in the company to meet the customer needs [1]. Currently, there are approximately 30,000 textile-related companies in United States, of which mostly use TQM tools for reducing the cost and increasing the customer satisfaction [1].

The basic raw materials of the textile industry are fibers. Normally, first, fibers are transformed into yarn and then transformed into fabric. The basic requirements for good quality of yarn include material twist, and count [6]. In spinning mills, quality control department plays a vital role in producing good quality of yarn. Yarn quality is measured by various parameters i.e. Yarn count, strength, count lea strength product (CLSP), Elongation, Evenness, IPI's, Yarn hairiness etc. In spinning mills, the main objective is to produce the desired count with good quality and low cost [7]. The basic characteristics of spinning are count and count uniformity. Since the yarn is represented by both of these characteristics and affect the yarn strength and its variability, the processes performance, and the fabric appearance [1].

Control charts are the most important tools of

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SQC, introduced by Walter A. Shewhart in 1920s as a simple and effective method to see and detect the occurrence of assignable causes of variability in manufacturing processes [8]. Variation in quality of the product arises in two forms; one is due to common cause and other is an assignable cause. Control charts are used to detect the change in the process mean as well as variances [9] and ultimately the assignable causes. Some studies have already been conducted to monitor and improve quality of textile products. Ahmed et al. [10] first time apply the control charts in textile spinning industry to monitor the 20s yarn quality characteristics without considering any condition for selecting suitable control charts. Kan and Lau [3] studied the effect of sampling methods (Fixed and random sampling) on yarn quality by using the t-test, and R control charts and found that random sampling results are reliable than fixed sampling. Felili and Fekraty [6] constructed the control charts on the basis of probability and fuzzy theory to monitor the yarn quality. They have found that fuzzy theory performs better than probability theory for monitoring product quality. Maros et al. [11] applied control charts on chenille yarns defect types to determine the variations. The data found to be autocorrelated, therefore they applied AR (1) and EWMA types control charts for monitoring and detecting defects in yarn types.

As the available literature shows that no study has been conducted to monitor the yarn count quality in a proper way. So, here our purpose is to apply the control charts with appropriate conditions to monitor yarn quality. The main logic of this application is to monitored yarn count quality for reducing the yarn waste and improving the yarn quality to satisfy the knitter and weaver customers.

2. MATERIALS AND METHODS

2.1 Data and Company

The data was taken shift wise from Colony Textile Mills (CTM) Ltd., Multan, Pakistan, concerning yarn quality characteristic. The fineness of the yarn is usually expressed in terms of its linear density or count. Therefore, yarn count samples are taken for product 40/1s from Autocone department and Ring frame departments to test the yarn quality regarding machines to test whether all machines give reliable quality. We select 50 random samples from each machine of both departments. The standard values given by American Society for Testing and Materials (ASTM) for the assessment of yarn count quality are given in the Table 1.

In textile spinning industry, there are two methods for process controlling, one is the online monitoring called Automation and other is the off line called Sampling method [12]. In this article, we use sampling method and the data sets are given in Table 5 and Table 6.

2.2 Sampling Technique

To get the reliable results, simple random sampling is used to collect the required data concerning yarn counts. In this study, we use $\overline{X}-R$ and $\overline{X}-S$ control charts to monitor the yarn quality variations. To proceed in our study, we have m samples and n subgroups. Sample size is how many times quality inspector is going to take the sample while subgroup size is how many units are taken at a time of product quality testing [9]. $\overline{X}$ control charts are used to detect the change in the average of product quality and R control charts are used to test the variation in product quality when subgroup size is less than 10, i.e., $n<10$ and product quality follow a normal distribution. While control charts are used when the subgroup size is at least 10, i.e., $n \geq 10$. The control limits for both of the stated control charts are used to test/monitor, whether yarn count quality in both Autocone and Ring frame departments was in control or not [9].

2.3 Control Limits for $\overline{X}$ Control Chart

The control limits for control chart as defined by Montgomery [9]

$$\textit{Upper control limit} = UCL = \overline{\overline{X}} + 3\frac{\hat{\sigma}}{\sqrt{n}}$$

$$\textit{Center Line} = CTR = \overline{\overline{X}}$$

$$\textit{Lower control limit} = LCL = \overline{\overline{X}} - 3\frac{\hat{\sigma}}{\sqrt{n}}$$

where, $\hat{\sigma} = \frac{\overline{R}}{d_2}$, $\overline{R}$

$\overline{R}$ is the average range and d_2 is constant depends on the subgroup size. The process is in statistical quality control, if all samples averages fall in the control limits otherwise the process indicated the out of control signals.

2.4 Control Limits for R Control Chart

The control limits for R control chart as defined by Montgomery [9]:

Upper control limit $= UCL = D_4\overline{R}$

Center Line = CTR $= \overline{R}$

Lower control limit $= LCL = D_3\overline{R}$

where, D4 and D3 are the constant values and also depend on the subgroup size. The process is out of control relating to variation, if any sample range crosses control limits, otherwise the process quality was in control.

2.5 Control Limits for S Control Chart

The control limits for S control chart as defined by Montgomery [9];

Upper control limit $= UCL = B_4\overline{s}$

Center Line = CTR $= \overline{s}$

Lower control limit $= LCL = B_3\overline{R}$

where, B4 and B3 are the constant values and also depend on the subgroup size and is the average sample standard deviations. These constants are available in [9, 13-14]. The process is out of control in terms of variation, if any sample variance crosses the control limits otherwise process quality was in control.

Since the data is taken from Autocone department of spinning mill, where each time seven machines are selected to test yarn count quality. We select 50 samples from these seven machines randomly for   control charts to determine the yarn count quality. Samples are selected 50 times, from 13 machines randomly for $\overline{X} - R$ control charts to test the yarn count quality in the Ring department. These data sets are given in Table 5 and Table 6. For data analysis to make a decision regarding yarn count quality on the basis of control charts, we used Statgraphics15 a statistical software [15].

2.6 Specification Limits for $\overline{X}$, R and S Control Chart

Specification limits are based on customer demands. This indicates that for each yarn product quality, target value (demanded) and standard deviation must be known in advance. So the specification limits are made on the basis of customer demands [9].

In this study, we use specification limits to test the yarn quality in the Ring and Autocone departments. We want to compare the output of yarn manufacturing process and voice of the customer (customer demands) by using control charts on the basis of specification limits.

2.7 Yarn Manufacturing Spinning Process

The most important system of making high quality yarn in textile is Ring Spinning. Spinning is the set of the process used in the production of yarns. The basic manufacturing process of spinning includes mixing, carding, combing, drafting, twisting and winding. As the fibers pass through these processes, and then successively transformed into the lap, sliver, roving and finally yarn. In textile spinning, yarn manufacturing is the final product (e.g. 40/1s). So the process of converting fiber into yarn is called yarn manufacturing spinning process and contains the following departments which are shown in Fig. 1.

For further detail about all departments functions see [16]. Each department contributes a significant role in yarn manufacturing process. In this study, we considered two departments to test whether the yarn count met the standard requirements of knitter and weaver or not? Because they demand a high quality of yarn to produce good quality of cloth.

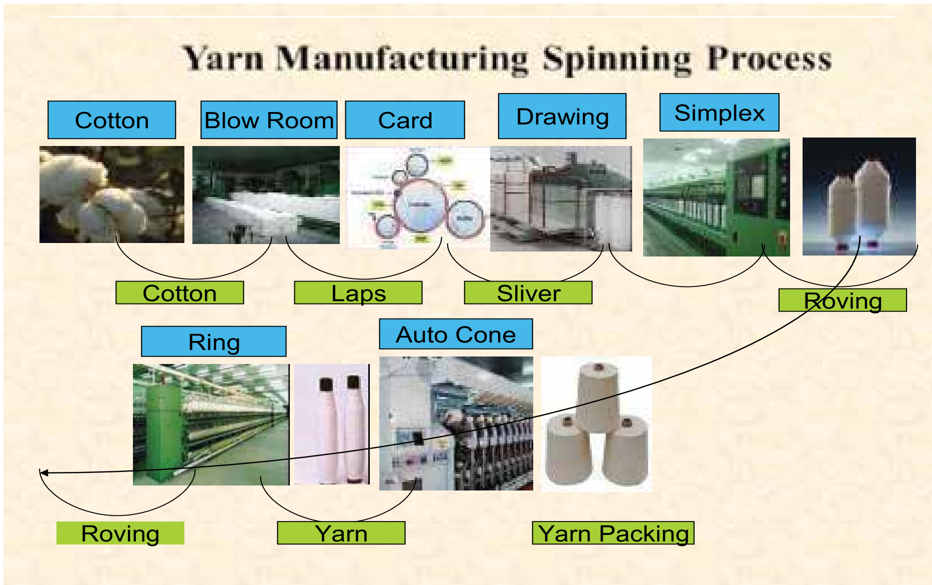

Fig. 1. Yarn manufacturing process.

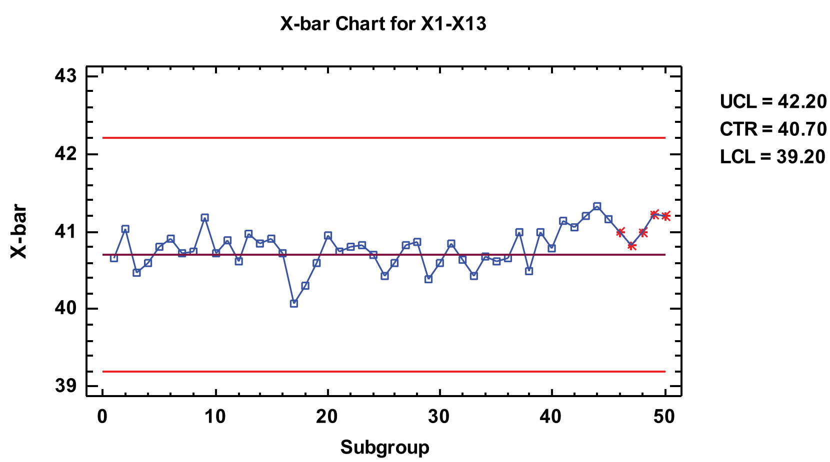

Fig. 2. Control chart for ring department.

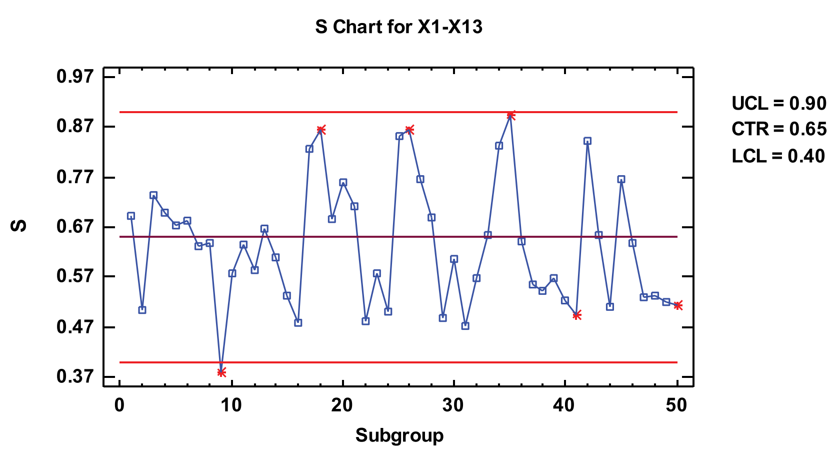

Fig. 3. S Control chart for ring department.

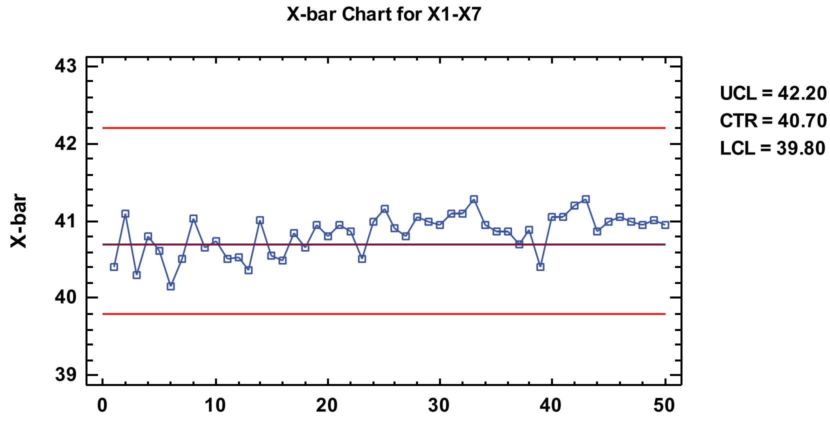

Fig. 4. control chart for autocone department.

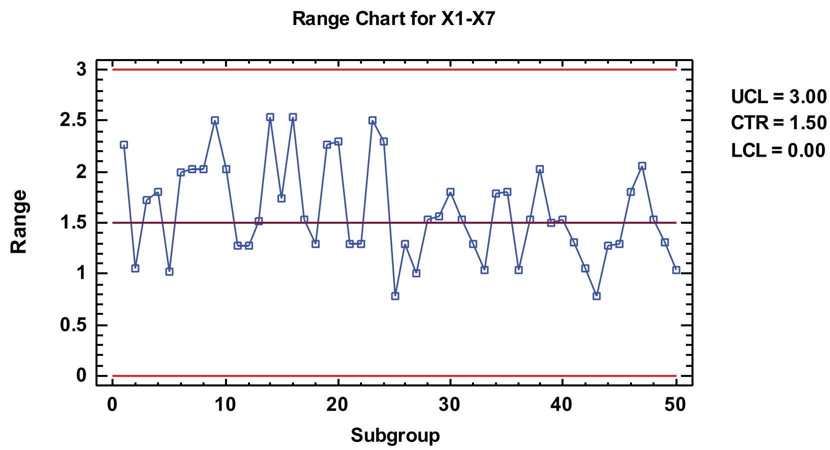

Fig. 5. Range control chart for autocone department.

Of the selected departments, 13 machines are installed in the Ring Frame department with their yarn count samples are represented as X1-X13. While 7 machines are installed in the Autocone department and their yarn count samples are represented as X1-X7.

3. RESULTS

3.1 $\overline{X}$-S Control Charts for Ring Frame Department

In Ring frame department, 13 machines were selected to measure the yarn quality. The samples were taken at the same time from 13 machines. Therefore, we used subgroup size 13 and applied $\overline{X}$-S.

This procedure of constructing the $\overline{X}$- R and $\overline{X}$-S control charts designed to allow the user to determine whether the data come from a Ring department process which was in a state of statistical control or not. The control charts were constructed under the assumption that the data follow a normal distribution with a mean equal to 40.7913 and a standard deviation equal to 0.646144 see Table 3. Of the 50 non-excluded points shown on the charts, none of the points was beyond the control limits on the first chart (see Fig. 2) while 1 was beyond the limits on the second chart (see Fig. 3). Since the probability of seeing 1 or more points beyond the limits just by chance was 0.0013, if the data came from the assumed distribution, we could declare the process to be out of control. From this, we found that average yarn count met the knitter demand but variation in the ring department did not meet the customer requirement.

Table 1. Specification limits of yarn quality characteristic

Yarn quality characteristic	USL	Target value	LSL
Average Yarn Count (NEC)	42.20	40.70	39.20

USL: upper specification limits; LSL: lower specification limits of yarn count quality. target value is the customer demanded value also termed as average demanded value.

Table 2. Specification limits for control charts, when standards are known.

Control Chart	LSL	Central Line	USL
$\overline{X}$	$\mu - A\sigma$	μ	$\mu + A\sigma$
R	$D_1\sigma$	$d_2\sigma$	$D_2\sigma$
S	$B_5\sigma$	$c_2\sigma$	$B_6\sigma$

$A, B_5, B_6, c_2, D_1, D_2$ and d_2 are constant and depend on subgroup size [9]

Table 3. Specification limits of $\overline{X}$ and S control charts and estimates for yarn count of ring department.

$\overline{X}$ Chart		S Chart		Estimates	
Period	#1-50	Period	#1-50	Period	#1-50
UCL:	42.20	UCL:	0.90	Process mean	40.8333
Centerline	40.70	Centerline	0.65	Process sigma	0.6461
LCL:	39.20	LCL:	0.40	Averages	0.6328
Beyond limits = 0		Beyond limits = 1		Sigma estimated from averages with bias correction	

Table 4. Specification limits of $\overline{X}$ and R control charts and estimates for Yarn NEC of Autocone department.

$\overline{X}$ Chart		MR(2) Chart		Estimates	
Period	#1-50	Period	#1-50	Period	#1-50
UCL:	42.20	UCL:	3.0	Process mean	40.8333
Centerline	40.70	Centerline	1.5	Process sigma	0.5933
LCL:	39.20	LCL:	0.0	Average Range	1.6125
Beyond limits = 0		Beyond limits = 0		Sigma estimated from average range	

3.2 $\overline{X}$ - R Control Charts for Autocone Department

In AutoCone department, there were 7 machines from which we measured yarn count (NEC) quality. The samples were taken at same time from seven machines. Therefore, we used subgroup size 7 and use and R Chart. Where X's represented the yarn count samples, from which $\overline{X}$ was calculated.

This procedure created the $\overline{X}$ and R charts for X_1-X_7. From Table 4, we observed that none of the points from $\overline{X}$ chart and from R chart were beyond the specification limits. Therefore, it is found that yarn count process is statistically in control. This indicates that the end product yarn quality meets the customer needs with controlled variation. So, it was found that the control charts were very useful in the spinning process to test and improve yarn quality like other product manufacturing industries.

Table 5. Autcone yarn count data.

S. No.	Aut-Mach-01	Aut-Mach-02	Aut-Mach-03	Aut-Mach-04	Aut-Mach-05	Aut-Mach-06	Aut-Mach-07
	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	41.2741	40.2487	39.5124	41.0129	41.5387	40.0003	39.273
2	40.755	41.0129	41.0129	40.755	40.755	41.5387	41.8067
3	40.755	40.2487	39.0364	40.5003	40.5003	40.755	40.2487
4	41.8067	41.2741	40.755	40.2487	40.755	40.755	40.0003
5	41.2741	40.755	40.2487	41.2741	40.2487	40.2487	40.2487
6	40.2487	39.273	39.7549	40.5003	40.755	39.273	41.2741
7	41.0129	41.5387	39.7549	40.5003	39.5124	40.0003	41.2741
8	41.5387	41.5387	40.0003	39.5124	41.5387	41.5387	41.5387
9	41.5387	41.0129	41.2741	40.0003	41.5387	40.2487	39.0364
10	41.5387	41.2741	40.0003	40.755	41.5387	40.5003	39.5124
11	40.755	41.2741	40.2487	40.0003	41.0129	40.0003	40.2487
12	40.0003	40.5003	40.2487	40.5003	40.755	41.2741	40.5003
13	40.2487	40.0003	40.2487	40.2487	41.2741	39.7549	40.755
14	39.273	41.8067	41.8067	41.2741	39.5124	41.8067	41.5387
15	41.0129	40.5003	39.273	40.755	40.2487	41.0129	41.0129
16	41.8067	40.5003	40.2487	39.5124	40.5003	41.5387	39.273
17	41.5387	41.5387	40.2487	40.0003	40.755	40.5003	41.2741
18	40.2487	40.755	40.5003	40.5003	41.5387	40.5003	40.5003
19	41.5387	41.5387	41.2741	39.273	40.755	41.2741	41.0129
20	41.8067	41.2741	41.5387	39.5124	41.5387	39.5124	40.5003
21	41.5387	41.0129	41.2741	40.2487	40.5003	40.5003	41.5387
22	41.5387	40.755	40.755	40.5003	41.5387	40.755	40.2487
23	40.2487	39.0364	41.5387	40.755	40.755	40.5003	40.755
24	39.5124	41.5387	41.5387	41.0129	40.755	40.755	41.8067
25	41.0129	41.5387	41.5387	41.0129	40.755	41.0129	41.2741
26	41.5387	41.0129	40.5003	40.755	40.2487	40.755	41.5387
27	41.0129	40.755	41.0129	40.0003	40.755	41.0129	41.0129
28	41.5387	40.0003	40.755	41.0129	41.5387	41.5387	41.0129
29	40.755	40.2487	41.8067	41.0129	41.5387	40.755	40.755
30	40.0003	41.8067	41.2741	40.755	41.2741	41.0129	40.5003
31	41.5387	40.5003	41.5387	41.5387	40.0003	41.5387	41.0129
32	40.2487	41.0129	41.0129	41.5387	41.0129	41.2741	41.5387
33	41.5387	41.0129	41.2741	41.5387	40.5003	41.5387	41.5387
34	39.7549	41.5387	40.755	41.0129	41.5387	41.2741	40.755
35	40.5003	40.0003	41.8067	41.5387	40.5003	40.755	41.0129
36	40.755	41.5387	40.755	40.5003	41.5387	40.5003	40.5003
37	40.5003	40.5003	40.5003	40.0003	40.5003	41.5387	41.2741
38	41.5387	41.5387	40.5003	41.0129	39.5124	41.0129	41.0129
39	41.0129	40.5003	40.0003	40.5003	40.755	39.5124	40.5003
40	41.5387	41.0129	41.0129	41.5387	41.0129	40.0003	41.2741
41	41.8067	41.0129	40.755	40.5003	40.755	41.0129	41.5387
42	41.0129	41.8067	41.0129	41.2741	41.8067	40.755	40.755
43	41.5387	41.5387	41.0129	41.5387	41.5387	40.755	41.0129
44	41.0129	41.2741	41.0129	40.0003	41.0129	40.755	41.0129
45	41.2741	40.755	40.2487	40.755	41.5387	41.5387	40.755
46	41.8067	41.8067	41.2741	41.2741	40.5003	40.755	40.0003
47	41.8067	41.5387	40.0003	39.7549	41.8067	40.5003	41.5387
48	41.5387	41.5387	41.0129	40.2487	41.2741	41.0129	40.0003
49	41.2741	40.755	41.2741	41.0129	40.5003	40.5003	41.8067
50	41.0129	40.5003	41.0129	40.5003	41.5387	40.5003	41.5387

Table 6. Ring, yarn count data.

S. No.	RY5-01	RY5-02	RY5-03	RY5-04	RY5-05	RY5-06	RY5-07	RY5-08	RY5-09	RY5-10	RY5-11	RY5-12	RY5-13
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
1	40.0003	40.5003	41.8067	40.5003	39.7549	41.0129	40.0003	40.5003	41.8067	40.5003	40.0003	40.5003	41.5387
2	40.5003	41.5387	41.0129	41.5387	40.5003	41.5387	40.5003	41.5387	40.755	41.5387	40.5003	40.5003	41.5387
3	39.7549	40.2487	39.273	39.5124	40.755	41.0129	40.755	41.2741	40.2487	41.5387	40.755	41.2741	39.7549
4	40.5003	41.0129	41.5387	40.755	39.5124	41.2741	40.0003	41.5387	39.7549	41.2741	40.0003	40.5003	40.0003
5	40.755	40.2487	40.2487	41.5387	41.0129	40.5003	39.5124	41.5387	40.755	41.5387	40.0003	41.2741	41.5387
6	41.0129	41.5387	41.8067	39.7549	41.0129	40.5003	41.0129	41.0129	41.5387	40.5003	39.7549	41.8067	40.5003
7	40.2487	40.755	40.755	39.5124	41.5387	40.2487	41.5387	40.2487	41.0129	41.0129	41.2741	40.0003	41.2741
8	41.5387	40.0003	41.2741	40.5003	41.2741	40.755	40.755	40.5003	41.5387	40.0003	40.2487	41.5387	39.7549
9	40.5003	40.755	40.755	41.0129	41.0129	41.8067	41.5387	41.0129	41.5387	41.2741	41.5387	41.2741	41.2741
10	40.2487	41.5387	41.8067	40.755	40.2487	40.5003	40.2487	40.755	40.755	40.2487	40.0003	40.755	41.5387
11	41.5387	40.0003	41.5387	40.2487	40.755	40.2487	41.5387	40.0003	41.5387	40.5003	40.755	41.5387	41.2741
12	40.2487	41.0129	40.755	40.5003	41.5387	40.5003	40.755	40.2487	41.0129	40.2487	41.5387	40.0003	39.5124
13	40.2487	41.0129	41.2741	41.5387	41.2741	40.2487	40.755	41.5121	40.5003	41.2741	41.5387	39.5124	41.8067
14	41.5387	40.5003	40.755	40.5003	40.755	41.8067	41.5387	40.5003	39.7549	41.5387	41.0129	40.5003	40.2487
15	41.2741	41.2741	40.5003	41.5387	40.0003	41.5387	40.5003	40.2487	40.755	40.755	41.2741	41.5387	40.5003
16	40.755	40.5003	41.2741	40.755	40.5003	40.755	40.0003	41.5387	40.2487	41.5387	40.2487	40.755	40.5003
17	39.273	39.0364	40.5003	39.5124	40.5003	39.0364	41.5387	39.7549	40.2487	40.5003	39.273	40.5003	41.2741
18	40.0003	39.5124	40.5003	39.273	39.0364	39.5124	40.5003	41.5387	41.5387	40.755	40.2487	40.0003	41.5387
19	40.2487	41.0129	40.2487	39.7549	41.5387	40.755	39.273	40.0003	41.0129	41.0129	41.0129	41.5387	40.2487
20	41.8067	41.8067	40.755	40.2487	41.5387	39.7549	41.5387	41.2741	40.0003	40.5003	41.5387	40.0003	41.5387
21	41.5387	40.5003	41.5387	39.5124	40.755	40.2487	41.5387	40.5003	40.2487	41.5387	40.0003	41.5387	40.2487
22	40.2487	41.0129	40.755	40.5003	41.5387	40.755	40.755	40.2487	41.5387	40.5003	40.755	40.2487	41.5387
23	41.0129	40.755	41.5387	40.5003	40.755	40.0003	41.5387	41.5387	40.5003	41.5387	40.0003	40.755	40.2487
24	39.7549	41.0129	40.5003	41.2741	40.2487	40.5003	40.755	40.2487	41.0129	40.5003	40.5003	41.5387	41.2741
25	39.0364	41.2741	41.0129	39.273	40.755	40.0003	40.5003	40.755	41.5387	39.273	40.0003	40.5003	41.5387

Contd...

Table 6 (Contd...)

26	41.0129	40.755	39.0364	40.755	41.8067	40.0003	41.2741	40.755	40.2487	41.2741	39.0364	40.2487	41.5387
27	40.0003	40.2487	41.8067	40.2487	41.0129	40.2487	41.2741	39.273	41.5387	41.5387	40.755	41.2741	41.5387
28	41.8067	40.5003	40.755	40.2487	41.5387	41.5387	40.5003	40.2487	41.5387	41.0129	41.5387	39.5124	40.5003
29	40.5003	40.0003	41.0129	39.7549	40.755	41.0129	40.5003	39.7549	39.7549	41.0129	40.5003	40.0003	40.5003
30	41.0129	40.5003	41.0129	40.2487	40.2487	41.5387	40.5003	40.2487	39.273	40.755	41.5387	40.5003	40.2487
31	40.0003	41.2741	41.0129	40.2487	41.0129	41.2741	41.5387	40.755	40.5003	41.0129	40.2487	41.2741	40.755
32	41.0129	40.5003	41.2741	41.5387	40.755	40.0003	40.2487	40.2487	41.2741	40.5003	40.0003	41.0129	39.7549
33	40.5003	40.0003	40.755	41.8067	41.0129	40.755	40.0003	40.2487	39.273	40.5003	39.5124	40.5003	40.755
34	39.273	40.5003	39.7549	41.8067	41.2741	41.0129	41.0129	41.2741	40.5003	41.0129	41.8067	39.5124	40.0003
35	40.2487	41.8067	41.5387	41.2741	39.273	40.0003	41.2741	39.5124	41.5387	40.0003	39.5124	41.2741	40.755
36	41.2741	41.2741	41.5387	40.0003	41.0129	39.273	40.5003	40.2487	40.2487	40.755	40.2487	40.755	41.2741
37	41.5387	40.5003	41.5387	40.2487	41.5387	40.5003	41.0129	40.5003	41.2741	40.5003	41.8067	41.5387	40.5003
38	40.2487	39.5124	40.755	40.5003	41.2741	39.7549	41.5387	40.755	40.2487	40.5003	40.5003	40.2487	40.5003
39	40.5003	40.755	41.5387	40.5003	40.5003	41.5387	40.5003	41.5387	40.755	41.5387	40.0003	41.5387	41.5387
40	41.5387	40.2487	40.755	40.755	39.5124	40.755	41.0129	40.5003	41.0129	41.5387	40.755	40.755	41.0129
41	41.0129	40.2487	40.755	41.5387	41.5387	40.755	41.5387	41.8067	40.755	40.5003	41.5387	41.2741	41.5387
42	40.0003	41.5387	41.5387	41.8067	41.2741	41.5387	40.0003	41.2741	41.0129	41.2741	39.0364	41.5387	41.8067
43	41.5387	40.2487	41.5387	40.2487	41.8067	41.2741	41.0129	41.5387	41.8067	40.0003	41.8067	41.8067	41.0129
44	41.0129	40.755	41.8067	41.2741	41.5387	41.8067	41.8067	40.5003	40.5003	41.8067	41.0129	41.8067	41.5387
45	40.0003	41.2741	41.8067	41.8067	41.8067	41.5387	41.8067	41.8067	40.0003	40.755	41.8067	40.0003	40.755
46	40.755	41.5387	40.0003	41.8067	41.2741	41.8067	41.0129	40.5003	41.2741	41.0129	40.0003	41.5387	40.2487
47	40.755	40.2487	41.0129	41.8067	40.5003	40.2487	40.2487	41.2741	40.755	41.5387	40.2487	41.2741	40.755
48	41.5387	39.7549	41.5387	41.0129	41.5387	41.2741	41.0129	40.755	40.5003	41.0129	40.755	40.5003	41.5387
49	41.8067	41.0129	41.8067	40.755	41.8067	41.0129	41.5387	40.755	41.5387	41.2741	40.0003	41.2741	41.2741
50	41.2741	41.2741	41.5387	41.8067	41.8067	40.755	41.2741	41.8067	41.0129	40.755	41.5387	40.5003	40.2487

These results are also indicated in Fig. 4 and Fig. 5.

4. DISCUSSION

As much more money is invested in the improvement of product quality, the organizations can survive only in a sense by improving their product quality [17]. Quality of product is affected by material, man, machines and environmental conditions. Textile products are playing a key role in making daily use products i.e. Cloth, trousers, shorts towels, etc. In all these products, yarn is contributing a significant role. To get good quality of these products, knitters and weavers demand a good quality of yarn. Therefore, it is necessary for the spinners, to monitor the yarn quality before launching their products into the market. This action may reduce the defects in yarn and yarn waste to increase the production of yarn with good quality. As we considered the two departments i.e. Ring and Autocone of the spinning industry. These two departments are the most critical for producing good quality of yarn. The main purpose of monitoring the yarn quality in these departments is to reduce the defects in the end product i.e. yarn. This can be achieved, if early detections are done. For early detection of a false alarm, control charts are most useful. As in our study, we used the control charts to monitor the yarn quality on the basis of sampling methods. If these charts are set on each machine through automation to monitor the yarn quality, early detections of false alarms are detected with minimum time. If such is done in Automation, textile spinners may reduce the number of employees who are appointed to take the samples for testing the yarn quality. Another advantage of yarn quality monitoring through automation with online monitoring of yarn quality using control charts is that production manager may increase yarn production with good quality. These charts may give misleading results, if quality analysts do not follow the proper way of selecting appropriate control charts [3]. If such is done in a proper way, these charts may give early alarm of the machines problems before it, these shutting down and the industry has severe loss in terms of material wastage, labor, and other expenses.

5. CONCLUSIONS

For testing quality of yarn, control charts are useful. In this study, we monitored yarn quality by machines in the Ring and Autocone departments by using control charts. We observed that in Ring department, yarn count quality variation was not in control as indicated by S-chart; however, in Autocone department both variation and targets were met the standard requirements of customers as indicated by R chart and X-bar chart, respectively. The yarn count quality was also tested by material, operators, and environmental condition by using control charts manually as well as online by monitoring system to improve yarn quality and gain a good reputation in the textile market. So the Xbar-S charts are a good tool for a subgroup of size of at least 10 while X-bar-R charts perform well for a subgroup of size less 10. They perform well to monitor yarn quality with the stated conditions. These charts can also be applied to monitor other yarn quality parameters.

6. REFERENCES

1. Dhillon, B.S. *Applied Reliability and Quality: Fundamentals, Methods and Procedures.* Series in Reliability Engineering. Springer (2007).
2. Townsend, T. & J. Sette. Natural fibers and the world economy. *Natural Fibres: Advances in Science and Technology Towards Industrial Applications* 12: 381-390 (2016).
3. Kan, C.W. & M.P. Lau. Effects of sampling methods on detection of yarn quality. *Research Journal of Textile and Apparel* 11(4): 71-79 (2007).
4. Clapp, T.G., A.B. Godfrey, D. Greeson, R.H. Jonson, C. Rich, & C. Seastrunk. Quality initiatives reshape the textile industry. *Quality Digest,* October 2001 (2001). https://www.qualitydigest.com/oct01/html/textile.html
5. Thomas, C.R., S.C. Maurice, S. Sarkar. *Managerial Economics,* 9th ed. Tata Mc Graw Hill, New Dehli, India (2010).
6. Feili, H.R. & P. Fekraty. Comparing fuzzy charts with probability charts and using them in a textile company. *The Journal of Mathematics and Computer Science* 1(4): 258-272 (2010).
7. Amin, M. A. Akber, M. Akram, & M.A. Ullah. Measurement system analysis for yarn strength spinning process. *International Research Journal of Finance and Economics* 82: 131-141 (2012).
8. Megahed, F.M. W.H. Woodall, & J.A. Camelio. A review and perspective on control charting with image data. *Journal of Quality Technology* 43(2): 83-98 (2011).

9. Montgomery, D.C. *Introduction to Statistical Quality Control,* 5th ed. John Wiley & Sons, New York (2005).
10. Ahmed, M.S., I. Javed, M. Ahmed, H.M. Naeem, & M. Sarwar. Application of statistical quality control in yarn spinning. *Pakistan Journal of Agricultural Sciences* 29(1): 25-30 (1992).
11. Maros, T., B. Viladimir, & T.M. Caner. Monitoring chenille yarn defects using image processing with control charts. *Textile Research Journal* 81(13): 1344-1353 (2011).
12. Engin, B.A. An application and use of economic and statistical control chart design for the textile yarn industry. *Quality Engineering* 16(4): 625-635 (2004).
13. Mullins, E. *Statistics for the Quality Control Chemistry Laboratory.* The Royal Society of Chemistry, UK (2003).
14. Damyanov, G.B., & D.S. Germanova-Krasteva. *Textile Processes: Quality Control and Design of Experiments.* Moment Press, New York (2013).
15. Levinson, W.A. *Statistical Process Control for Real World Applications.* CRC Press, Taylor & Francis Group (2010).
16. Lawrence, C.A. *Fundamentals of Spun Yarn Technology.* CRC Press LLC. (2003).
17. Amin, M., M. Amanullah, & A. Akbar. Quality variation minimizer: A new approach for quality improvement in textile industry. *Pakistan Journal of Scientific and Industrial Research, Series A: Physical Sciences* 59(2): 109-113 (2016).