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PROCESS CAPABILITY ANALYSIS: AN EFFECTIVE TOOL FOR ASSESSMENT OF YARN MANUFACTURING PROCESS

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ABSTRACT

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Continuous improvement of a process is the prime focus for management and process capability analysis indices which are an effectual instrument for that. The application of process capability analysis as an effective tool of SPC was carried out for 3 different cases in carded hosiery yarn manufacturing. The actual data distributions of the carded hosiery yarn were checked and analyzed for determination of the process capability. The process capability analysis provide the process capability indices $C_{p,}$ C_{pu}, C_{pl} & C_{pk} which indicate the stability of the process. Here three different cases were studied for same parameters such as Ne, CV_{cb}%, CSP and IPI. The study showed the process capability indices for all parameters for the three examined cases. As an outcome of the study it was found that for all cases the process means were deviated from the target means which indicated that the process mean is needed to shift to the target mean by taking necessary measures or redefining the specification limits if necessary to make the process capable.

Key words: *process capability analysis, quality improvement, carded hosiery yarn*

INTRODUCTION

The textile industry has become a field of great competition nowadays due to globalization. The demands of the customers are increasing day by day in terms of both quality and quantity. Thanks to the effort of the machine manufacturers, nowadays the productivity level of the machines used have improved vastly and is still improving. By using these modern machines, a manufacturer can meet up the quantity demand of the customers. But how can quality be improved? The average quality level both as required and as produced is enhancing rapidly. It is alarming for a yarn manufacturer of Bangladesh that the quality level of competitor countries like China, Indonesia, Vietnam, India & Pakistan is booming rapidly. Also, with the increasing productivity level, the quality is needed to be improved accordingly. So, this question, "How to improve and maintain the Quality Level of yarn?" is a burning question for a yarn manufacturer. To handle these requirements, a spinning mill has to use the available information, analyze them and take proper actions to improve quality. These actions include, maintaining the quality level required by strict monitoring and minimizing variations in the daily productions by finding sources of variations, solving them and minimizing outliers.

To detect and analyze the variations in the quality parameters of the produced yarn, an effective tool is required. For this purpose, statistical tools can be used. The process capability study is one of them and is helpful in analyzing the quality and efficiency of the process. The process capability analysis has been widely adopted as the ultimate measure of performance to evaluate the ability of a process to satisfy the customers in the form of specifications (English and Taylor, 1993).

Process analysis through SQC or SPC tools can provide insight view of the nature of the problem. If the nature of the problem is known, appropriate measures can be taken beforehand to obtain stability of the process. This stability provides predictability of the process output.

Nowadays in the yarn manufacturing industry, quality parameters of the produced yarn and predecessor materials are tested in both scheduled and random manner. The results of all these tests are analyzed and compared only to the specification limits. But, the variation of the parameters within the specified range and also the frequency of occurring of outliers is not regularly analyzed. By the analysis of these two aspects, we can quantify the capability of the process, identify the variations and also can provide information about the fields where measures should be taken to maintain the product within specification range and increase the capability of the process.

BACKGROUND

To ensure the quality of yarn, the industries mainly depend on the measuring of some parameters such as Fineness of yarn (Cotton English count – Ne), CV_{cb}%, CSP and IPI. But the product testing cannot provide any sustainable long term confirmation for quality. To attain a long-term indication for quality product the process should be focused on the basis of process capability analysis. The widely used capability indices provide useful quantitative measures of process potential and performance in manufacturing industry. Again Process-capability analysis is a way of determining the ability of a process for manufacturing products within the specifications (Ramakrishnan *et al.* 2001; Montgomery 2005). This paper studied the application of process capability analysis for assessment of yarn manufacturing process.

Parameters

Cotton English Count

Cotton English Count is a measure of fineness or linear density. In this system, the yarn number is measured by the number of 840 yard hanks in one pound of the material (Grover and Hamby, 1963). Under this system the higher the number, the finer the yarn.

Count CV% (CV_{cb} %)

The coefficient of variation (abbreviated CV %) is a measure of the relative dispersion and useful in comparing the dispersions of two or more processes or materials or in comparing the same types of materials produced at different times. It is calculated as the variation of the standard deviation with respect to the average of the data (Grover and Hamby, 1963). Count CV% is obtained from the values of individual observations for count testing.

CSP

The count strength product (CSP or LCSP) is a measure used for cotton yarns and is the product of the yarn count and the lea (hank) strength. It is based on measuring the strength of an 80 turn hank made on a 1.5yd wrap reel to give a total length of 120yd. The strength is usually measured in pounds force (lbf). The value enables a comparison to be made among yarns of a similar but not necessarily identical count in the same way that tenacity values are used. (Saville 1999).

IPI

IPI stands for Imperfection Index. For ring spun yarn, IPI is the summation of +50% thick place, -50% thin place and + 200% Neps. By IPI, we can get an idea about total number of different objectionable imperfections present in the yarn at a glance.

Process capability analysis

The Process capability analysis is extensively applied to determine the ability to manufacture products within the specification limits. It can be applied in all stages of manufacturing like planning, designing, product cycle, process etc. (Sagbas 2009). For the process capability analysis, four capability indices were used (Hasin 2007).

1. C_p = Process Potential Index
2. C_{pk} = Process Performance Index.
3. C_{pu} = Upper Process Performance Index.
4. C_{pl} = Lower Process Performance Index.

C_p: Process potential index is related to process variability. It is the ration between the allowable process spread and actual process spread.

$$C_p = \frac{\text{allowable process spread}}{\text{actual process spread}} = \frac{\text{USL - LSL}}{6\sigma}$$

where, USL = Upper specification limit

LSL = Lower specification limit

σ = Standard deviation of observations

C_{pk}: Process performance index is the measurement of process capability with respect to mean. It measures capability of the process at the specification limit, which has the highest chance of a part going beyond the limit. And naturally, that side will have the highest chance, to which the process has shifted. So, the performance of the process is measured both on the upper side and lower side of the specification by C_{pu} and C_{pl} respectively and process performance index is the minimum of them.

$$C_{pu} = \frac{\text{allowable upper process spread}}{\text{actual upper process spread}} = \frac{\text{USL} - \overline{X}}{3\sigma}$$

$\overline{X}$ = mean of the observations.

$$C_{pl} = \frac{\text{allowable lower process spread}}{\text{actual lower process spread}} = \frac{\overline{X} - \text{LSL}}{3\sigma}$$

C_{pk} = minimum (C_{pu}, C_{pl})

A process is considered "capable" if the process spread is less than or equal to the specification limits. If it goes sufficiently beyond these specification limits, the process is judged "not capable".

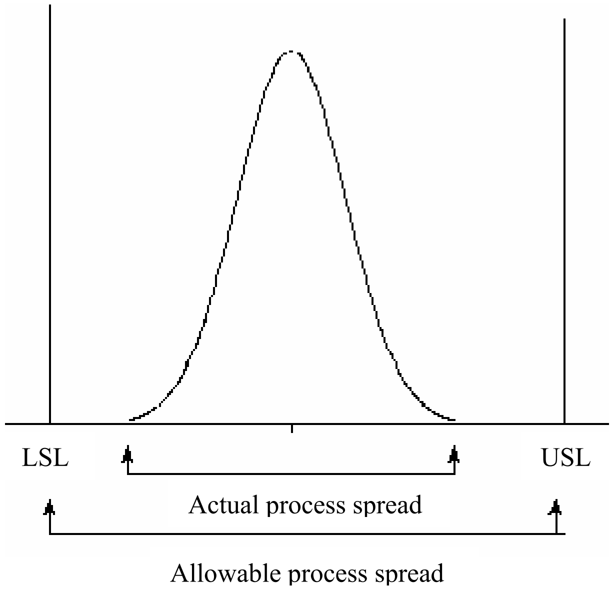

Fig. 1. Allowable vs. actual process spread (source- Hasin 2007)

According to the Empirical rule of statistics, under the bell shaped Normal Distribution assumption, almost 99. 7% of the data should fall inside ±3σ spread from the mean (Lind *et al.* 2005). When process is improved through adjustment in process parameters, then the actual process spread may narrow down. This continuous improvement makes the actual spread steeper. When this happens, C_p value increases, which is desirable. A commonly accepted notion in quality control is to have C_p value of 1.33 for an established and stable manufacturing process.

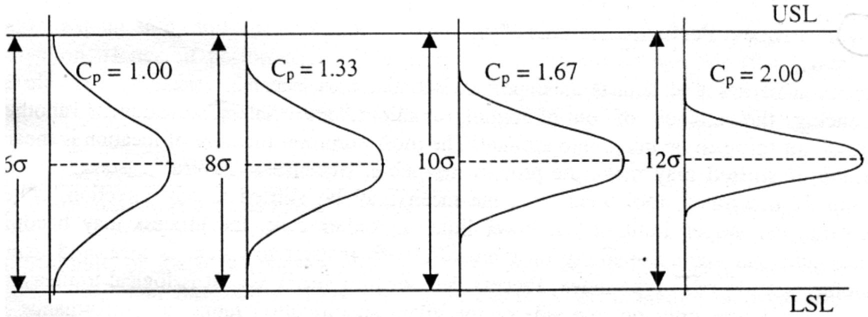

Fig. 2. Relative values of allowable vs. actual process spread (source- Hasin 2007)

The above indices can assess capability of performance of a process as follows (Sagbas 2009):

Table 1. Process estimation based on the indices C_p and C_{pk}

Capability Index	**Estimation of the process**
$C_{pk} = C_p$	Process is placed exactly at the center of the specification limits.
$C_p < 1$	Process is not adequate.
$1 \leq C_{pk} < 1.33$	Process is adequate.
$C_p \geq 1.33$	Process is satisfactory enough.
$C_p \geq 1.66$	Process is very satisfactory.

METHODOLOGY

In this study, three cases of producing 24 Ne, 30 Ne and 34 Ne carded hosiery yarn were selected. The specification limits of above mentioned quality parameters for each case were selected from established and renowned industrial standards. For each case samples were collected from ring frames in a random manner but from the middle position of ring bobbin to ensure the data reliability. 30 observations of each case were considered where each observation was the average of 10 subsequent tests. The yarn samples were tested by USTER Autosorter – 4, USTER Evenness Tester – 5 and Eureka Lea Strength Tester. Finally the data were analyzed using Minitab®-16.1.1.

DATA ANALYSIS

The specification limits for the quality parameters were considered as follows:

Table 2. Specification limits and their sources

Quality Parameter	Specification limit	Source
English Count	±1.3% of nominal count	USTER Statistics 2007.
Count CV (CV_{cb}%)	0 – 1.5	R.I. Testing Norms 2007.
Lea CSP	2300 - 2700	USTER Statistics 2007.
Imperfection Index (IPI)	USP 50% standard.	USTER Statistics 2007.

The data were analyzed considering the specifications of table – 2 and the following figure- 3 to 14 were obtained from Minitab® 16.1.1.

RESULT AND DISCUSSION

Case – 1: 24Ne Carded Hosiery

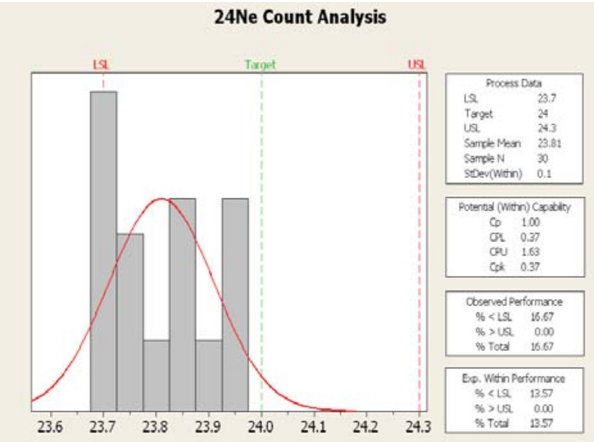

Fig. 3. Data distribution of 24 Ne count

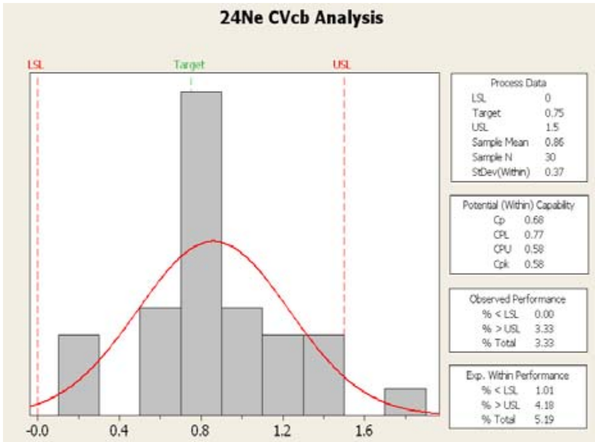

Fig. 4. Data distribution of 24 Ne CVcb

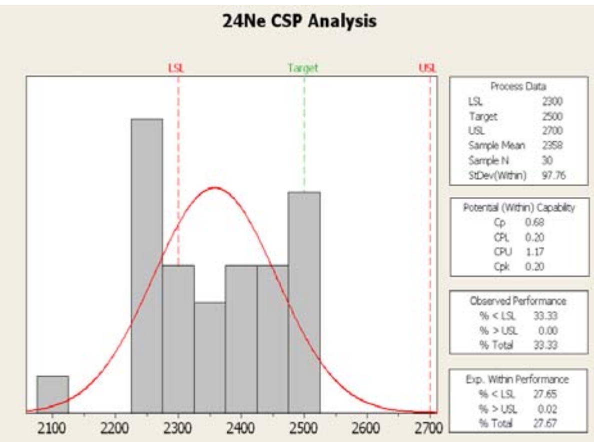

Fig. 5. Data distribution of 24 Ne CSP

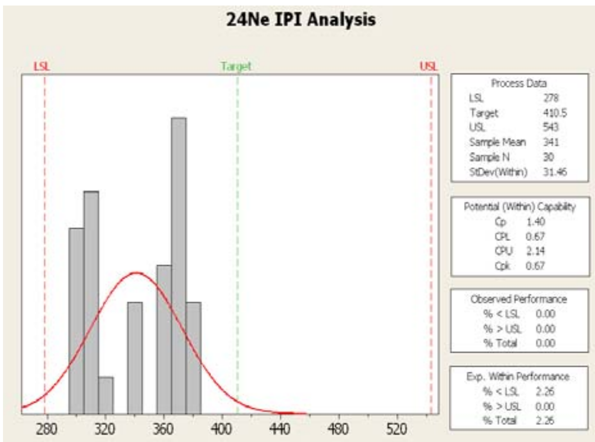

Fig. 6. Data distribution of 24 Ne IPI

The charts above show that the process is incapable regarding CV_{cb}% and CSP as C_p indicate that the observed values ranged outside the limits of the specification. Regarding analysis by Count, the actual and process spread are same as C_p=1 but C_{pk} indicates the shifting of the values towards the lower limit and 13.57% of values lie out of the lower limit, making the process incapable. Only analysis of IPI values shows the process capable.

Case – 2: 30 Ne Carded Hosiery

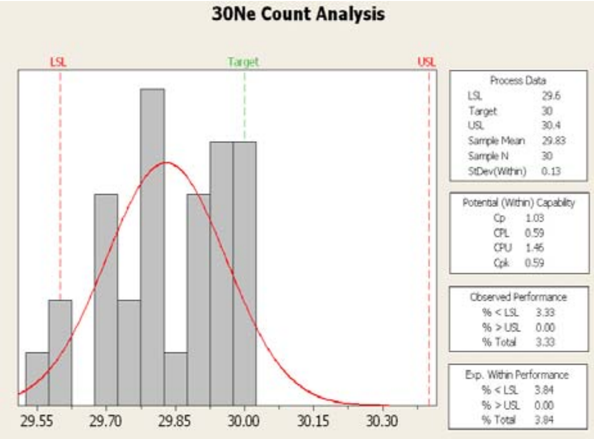

Fig. 7. Data distribution of 30 Ne count

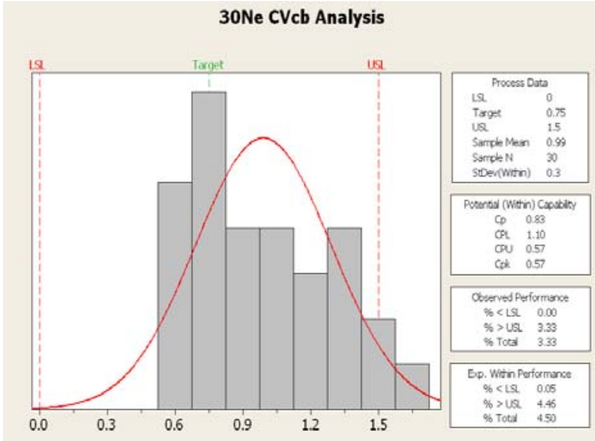

Fig. 8. Data distribution of 30 Ne CVcb

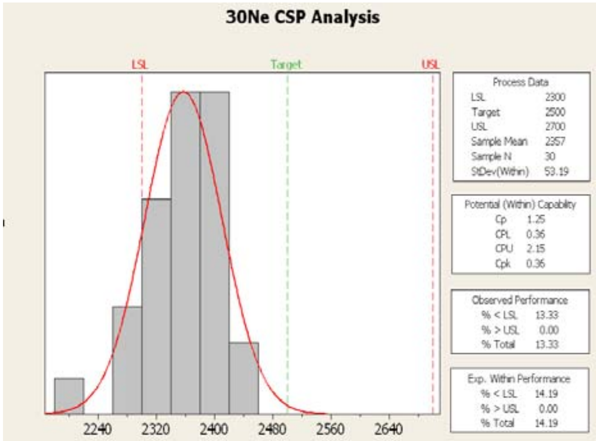

Fig. 9. Data distribution of 30 Ne CSP

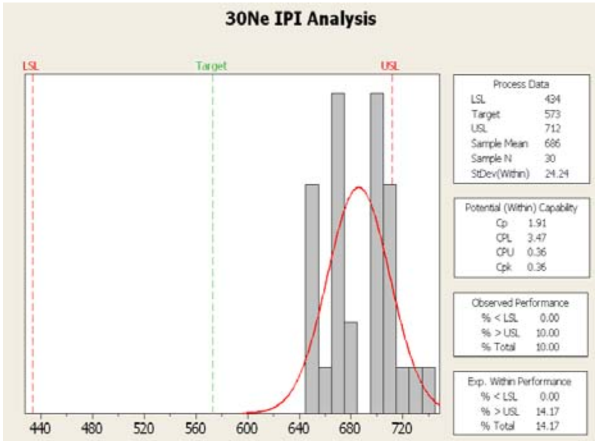

Fig. 10. Data distribution of 30 Ne IPI

In this case, the process was found incapable since in all four parameters, the observed values spread significantly outside the specification limits.

Case – 3: 34 Ne Carded Hosiery

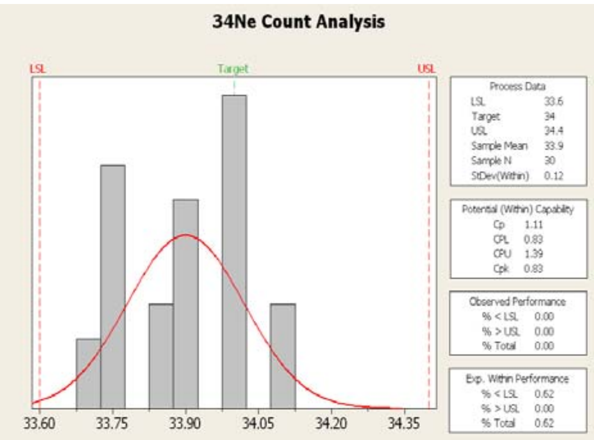

Fig. 11. Data distribution of 34 Ne count

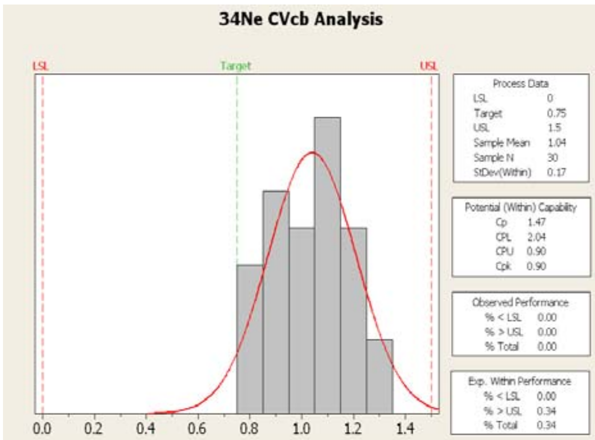

Fig. 12. Data distribution of 34 Ne CVcb

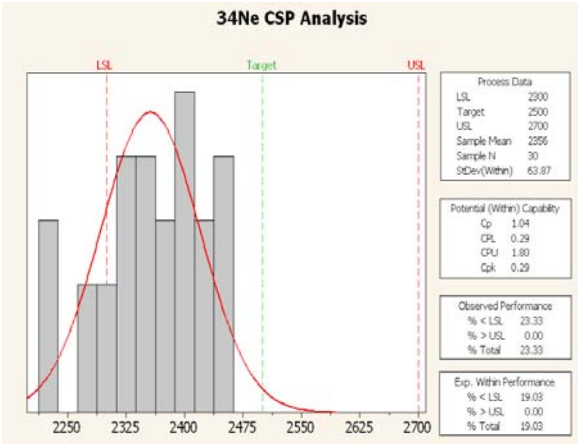

Fig. 13. Data distribution of 34 Ne CSP

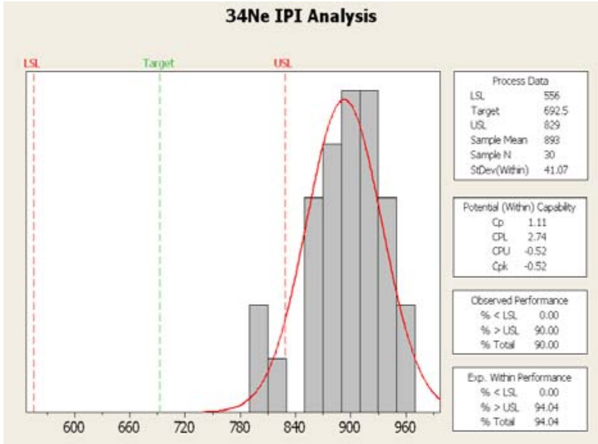

Fig. 14. Data distribution of 34 Ne IPI

Among the three cases observed, the analysis proved this case most capable. In all four parameters, the C_p values signify that the process spread is within the specification limits. As Count and CV_{cb}% regards, the process means shifted towards the lower limit and higher limit respectively but all the data are within the perimeter. But in the observation of CSP and IPI values, C_{pk} indicate presence of the values significantly outside the limit.

CONCLUSION

Among these three cases, the production process of 34 Ne carded hosiery yarn was found capable regarding count and CV_{cb} while the process of 24 Ne capable for IPI only and the process of 30 Ne incapable for all four parameters. As conclusion, the process of 34 Ne carded hosiery yarn manufacturing demonstrated better capability. To improve the capability it is necessary to take proper measures in enrichment of the quality of the produced yarn in terms of both short term and long term variations. Also, in all the cases, the values of IPI of yarn were shifted to the upper specification limit and a bunch of them were out. From this study, it appears that there is also a necessity to redefine the specification limits for analysis of IPI. Process capability analysis is recognized nowadays as a vital part for application of statistical techniques for quality assurance. But in Bangladesh, it is not a mostly used technique. Foremost reason behind this is the lack of trained employees to implement it and also inadequate investment in this respect. For attainment of process quality improvement, wide and continuous application of SPC is a compulsion.

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