International Journal of Applied Engineering Research ISSN 0973-4562 Volume 16, Number 9 (2021) pp. 772-777
© Research India Publications. https://dx.doi.org/10.37622/IJAER/16.9.2021.772-777

Assessment of Quality of Cloths Processed in Two Industries by Statistical Methods

Nirmal Kumar Singh[1]
Department of Mechanical Engg
IIT(ISM) Dhanbad- 826004 Jharkhand. India.

ORCID : 0000-0002-2773-4261
Web of Science Researcher ID A-3281-2015
Scopus Author ID: 57193669685

Vidhika Tiwari[2]
Department of Mechanical Engg
DPGITM Gurugram-122001.India

ORCID : 0000-0001-5275-1736

Abstract

Various quality characteristics e.g. Mass/m^2, Breaking Strengths, Nos. of threads per decimetre, Heat shrinkage and Relaxation shrinkages all in warp and weft directions respectively; Polyester and Cotton contents (%), Water solubility and pH value of cloths i.e. plain weave polyester and cotton khaki or LBG (Light Blue Grey), purchased from approved sources by two different industries, have been assessed and compared by application of statistical methods e.g. Mean, Standard Deviation, Frequency Distribution, Process Capability Analysis, etc. Bivariate Process Capability indices and relationship between Breaking strength and Nos. of threads per decimetre in warp and weft directions respectively have been calculated and discussed. The causes of low process capability measures and high variability of various quality characteristics of cloths have been discussed in detail. Remedies for the improvement of their low process capability measures have been suggested.

Keywords: Quality Characteristics of cloth, Statistical Methods, Process Capability Analysis, Variability, Remedies.

1. Introduction

Cloth plain weave Polyester and cotton Khaki or LBG (Light Blue Grey) is processed by two industries viz. Industry I and Industry II from basic materials known as grey cloths. Grey cloths are procured from approved and stabilized sources by two industries. These cloths are used for the manufacture of various made-up garments e.g. shirt, shorts, trousers, slacks and bush shirt etc. The specification requirements of various quality characteristics for grey cloth e.g., mass/m^2, breaking strengths in warp and weft directions ends/dm, picks/dm etc. are maintained during the production before manufacture of garments.

Process capability Analysis plays a very important and essential role for the control and improvement of quality characteristics of the product produced by the manufacturing process. It is study for the analysis of the process capability of the manufacturing process. The study includes the theoretical development of some new process capability measures for quality (or reliability) characteristics of the products well as the practical application of conventional/traditional and some new indices in the manufacturing industries.

Lawrence [1] discussed about continuous-filament yarns (or filament yarns) which are used to produce a wide range of woven and knitted fabrics for various textiles and clothing. A classification has been mentioned for yarns and the yarn-count system used for specification has been explained. The extrusion-spinning systems for producing filament yarns and various texturing processes for imparting visual and tactile characteristics to them have also been described. The properties of continuous-filament yarns and means for imparting added functionalities have been discussed and examples of applications for these yarns and future trends in their development have been given. Wilson [2] discussed textile fabrics and their fibres and yarns. Ongoing research into fibres, yarns and fabrics means that new materials and processes are continually being developed with environmental issues driving the development of more efficient processing technologies and new sustainable fibres. Merati and Semnani [3] discussed that textile faults have traditionally been detected by human visual inspection. The evaluation of textile quality by soft computing techniques has infused fresh vitality into conventional textile industry using advanced technologies of computer vision, image processing and artificial intelligence. They described the methods for detection of textile defects, quality control, grading and classification of textile materials based on image processing and modern intelligence technology.

Das [4] discussed the use of statistical tools, such as measurement of variability, differences between means, significance of variables, control charts and hypothesis testing in textile industries. He has also discussed the necessity to test the fibre, yarn and fabric for their quality while purchasing in bulk in the industry. An entire batch cannot be accepted by testing only one or two samples. Acceptance sampling technique is a reliable method of selection of samples from bulk. The quality of the product or process can be identified by control charts. Certain controllable variables such as count of yarn, strength, etc. have taken for analysis and their importance is found by statistical tests of significance. Different statistical techniques and their applications in textile industry have been explained with relevant examples.

The analysis of various quality characteristics of yarns of the cloth e.g., mass/m^2; breaking strengths, Nos. of threads per decimetre, heat shrinkage and relaxation shrinkages all in warp and weft directions by statistical methods is generally missing in literatures of textile engineering. Statistical methods e.g. mean, standard deviation, frequency distribution, dispersion, process capability (for sample it is called product characterization) analysis have been used for the comparative assessment of quality characteristics of yarns of the product (cloth) in this present paper.

Kane [5] introduced Process Capability index Cp also called Process Potential index which considers spreads only.

$$Cp = (U-L) / 6s \tag{1}$$

Where U = Upper specification limit, L = Lower specification limits and s = Standard deviation

$Cp \geq 1$ for a capable process.

Kane [5] also introduced Process Capability indices (called Process Performance indices) as:

$$CPL = (\overline{X} - L) / 3s \tag{2}$$

$$CPU = (U - \overline{X}) / 3s \tag{3}$$

$$Cpk = \text{Min}(CPL, CPU) \tag{4}$$

Where, $\overline{X}$ = Mean, CPU, CPL, $Cpk \geq 1$ for a capable process.

$$K = \frac{m-\mu}{\left(\frac{U-L}{2}\right)}, \tag{5}$$

where $m = \frac{U+L}{2}$ and $-1 < K < 1$ (K = Process off-centering Index)

The indices Cp, CPL, CPU and Cpk do not consider of the target value. Chan, Cheng and Spiring [6] point out that while ensuring that the process spread, is within the specification limit, fails to take into account of the target value of the process. To correct for this the authors suggested a modified version of Cp. Thus, this index is defined as

$$Cpm = \frac{U-L}{6\tau} = \frac{Cp}{\sqrt{1+\left(\frac{\mu-T}{\sigma}\right)^2}},$$

Where $\tau^2 = s^2 + (\mu - T)^2$ and T = Target (6)

$Cpm \geq 1$ for a capable process and Cpm < Cp.

The index Cpm was proposed independently by Taguchi and Hsiang [7]

Mukherjee and Singh [8] introduced Process Capability index for two correlated quality characteristics called Bivariate Process Capability index as

$$PCR_b = \frac{D}{s_1 s_2}, \quad \text{Where } D = (U_1 - L_1)(U_2 - L_2)C(\rho) \text{ and}$$

$$C(\rho) = \frac{1}{4hk} \tag{7}$$

U_1/U_2, L_1/L_2 are USLs and LSLs of two correlated characterizes.

ρ = correlation coefficient of two characteristics.

h and k may be taken from Mukherjee and Singh [7] table.

2. Comparative Assessment of Quality Of Cloth Plain Weave Polyester and Cotton, Khaki Or Light Blue Grey (L.B.G.) Processed By Two Industries

Cloth Plain weave Polyester and Cotton Khaki or LBG is processed by two industries viz. Industry I and Industry II from the basic material known as Grey Cloth. Grey Cloth is procured from other approved and established sources by the two industries. This cloth is used for the manufacture of various made-up garments e.g. shirts, shorts, trousers, slacks and bush shirts etc.

Statistical methods e.g., Mean, Frequency Distribution, Dispersion, Process Capability (for sample it is called Product Characterisation) Analysis and Regression Analysis etc. have been used for the comparative assessment of the quality of the product.

2.1 Sample Observations / Data

Samples are drawn from the processed bales as per sampling plan and tested for its quality characteristics in accordance with the specification requirements. Some relaxation from the specification requirements is allowed in special cases without affecting the serviceability and durability of the store.

It is important to note that the sample data / observations are non-homogenous and non-uniform because the samples are drawn from intermittent processed bales. All computations are generally for large sample sizes. So, it is quite likely that statistics for each and every quality characteristic of the product calculated from the test data of samples will represent corresponding parameters of the processed bales as a whole. However, statistics of the quality characteristics will not show dynamic behaviour of the process.

2.2 Analysis and Interpretation of Data

2.2.1 Mass/m² (in gm/m²): Specification requirement - 190 ± 5%

- For Industry I: n (No. of observations) = 87

  $\overline{x}$ =196.35, s = 4.74

  K= 0.67, C_p = 0.67

- For Industry II : n = 71

  $\overline{x}$ =188.73, s =9.22

  K= - 0.14, C_p=0.34

It is observed from Figure 1 that both the distributions are incorrectly located with respect to the specification limits. A large part of the highly dispersed distribution of the characteristic in Industry II lies below the LSL with smaller part exceeding the USL. In distribution for Industry I is more or less bell-shaped but its mean is to the right of $\left(\frac{USL+LSL}{2}\right)$

causing a tail beyond the USL. These features of the distributions cause low process capabilities. While for Industry I, a shifting of the process mean to the left may improve matters, significant process improvement to reduce process variability is needed in the other case.

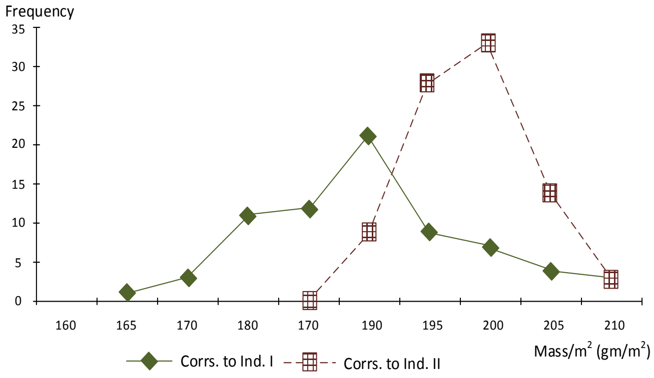

Fig.1. Distribution of Mass/m^2

Low values of process capability indices are mainly due to high process variability occurring due to in-homogeneity/non-uniformity of the observations of the quality characteristics of the samples taken from the intermittent bales.

2.2.2 Breaking Strength (in Warp Direction) (in Newton):
Specification requirement: 880 ± 5%

- For industry I : n = 87

  $\bar{x}$ =1148.37, s = 100.26

  K = 6 i.e., most of the observations lie for beyond the USL

  C_p = 0.15, *Cpm* = 0.05

- For Industry II : n = 71

  $\bar{x}$ = 1095.31, s = 100.54

  K = 4.9 i.e., most of the observations lie for beyond the USL

  C_p = 0.15, C*pm* = 0.06

From the above analysis it is observed that higher and higher values of the characteristic for beyond USL have been accepted considering the strength and the durability of the product resulting in low process capability in both the cases. The shifting of process mean toward the target and significant process improvement to reduce variability in future bales is needed to improve process capability.

2.2.3 Breaking Strength (in Weft Direction) (in Newton):
Specification requirement: 640 ± 5%

- For Industry I: n = 87

  $\bar{x}$ = 884.64 , s = 76.66

  K = 7.6 i.e., most of the observations lie far beyond USL

  Cp = 0.14, *Cpm* =0.04

- For Industry II : n = 71

  $\bar{x}$ = 850.55, s = 79.04

  K = 6.6 i.e., most of the observations lie far beyond USL

  Cp = 0.14, *Cpm* = 0.05

From the above analysis it is observed that higher and higher values of the characteristic for beyond USL have been accepted considering the strength and durability of the product resulting in low process capability in both the cases. The shifting of process mean towards the target and significant process improvement to reduce variability in future bales is needed to improve process capability.

2.2.4 No. of Threads per Decimetre (dm) in Warp Direction (Ends/dm):

Specification requirement: 260 ± 5%

- For Industry I: n = 87

  $\bar{x}$ = 253.96, s = 3.65

  K = -0.46, Cp = 1.18

- For Industry II : n = 71

  $\bar{x}$ = 254.83, s = 4.86

  K =- 0.39, Cp = 0.90

From Figure 2 it is observed that both the distributions are within the specification limits. The distribution of the characteristic in the industry I is bell shaped while it is bimodal in the other. In both the industries the process is off centered towards the left and the mean lie below the midpoint of the specification limits or the target. The process in the Industry I is capable, but it is not capable in the other due to high variability of the characteristic. The process capability in the industry I can be further improved by shifting the process mean toward the target value whereas significant process improvement is needed to reduce the process variability and shift the process mean towards target in the other in future bales.

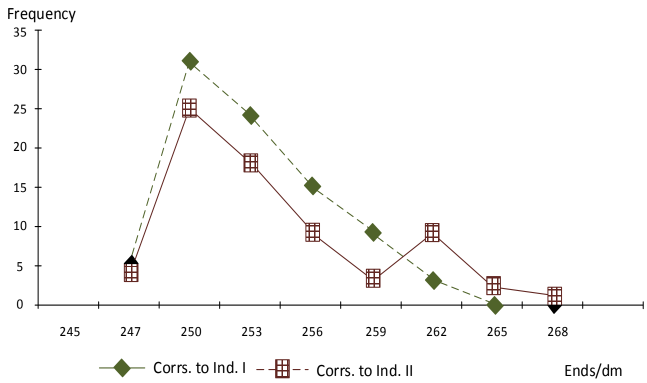

Fig.2. Distribution of Ends/dm (260 ± 5%)

***2.2.5 No. of Threads per dm in Weft Direction** (Picks/dm)*:
Specification requirement - 190±5%

- For Industry I: n = 87

  $\bar{x}$ =198.67, s = 6.06

  K = 0.91, Cp = 0.52

- For Industry II: n = 71

  $\bar{x}$ =1 98.25, s = 6.76

  K = 0.86, Cp = 0.55

It is observed from the Figure 3 that both the distributions are bell shaped and are incorrectly located with respect to the specification limits. The process means are near to the USL. The large part of the highly dispersed distribution lies outside the USL resulting in low process capability. Significant process improvement and shifting of the process mean towards left is needed to reduce process variability and to improve process capability.

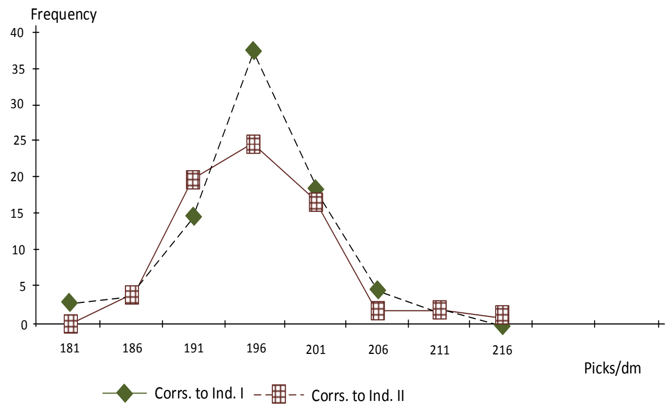

Fig.3. Distribution of Picks/dm (190 ± 5%)

2.2.6 Heat Shrinkage (Warp Direction) *:* Specification requirement - 2% max

- For industry I : n = 24
  $\overline{x}$ = 1.09, s = 0.33
  C_{pk} = 0.92
- For Industry II: n = 27
  $\overline{x}$ = 0.81, s =0.22
  C_{pk} =1.80

It is observed from the above analysis that for industry I the process is within the specification but highly dispersed. Significant process improvement is needed to reduce variability in this case.

2.2.7 Heat Shrinkage (Weft Direction)*: Specification requirement - 2 % max*

- For Industry I : n =24
  $\overline{x}$ = 0.63, s = 0.36
  Cpk = 1.26
- For Industry II : n = 27
  $\overline{x}$ = 0.55, s = 0.32
  Cpk = 1.53

It is observed from the above analysis that the processes in both cases are capable due to the low process mean but the variability is high like discussed in Heat Shrinkage (Warp direction). Significant process improvement is needed to reduce process variability in Industry I.

The revision of the specification requirement is needed because the heat shrinkage in weft direction may be less than the heat shrinkage in warp direction.

2.2.8 Relaxation Shrinkage (Warp Direction) : Specification requirement - 1 % max

- For Industry I : n = 27
  $\overline{x}$ = 0.73, s = 0.28
  Cpk = 0.32
- For Industry II : n = 27
  $\overline{x}$ = 0.84, s = 0.23
  Cpk = 0.23

It is observed that both cases the process mean lies below the maximum limit but the process variation is very high resulting in low process capability Significant process improvement is needed to reduce process variability in both the cases.

2.2.9 Relaxation Shrinkage (Weft Direction) *:* Specification requirement - 1 % max

- For Industry I : n = 27
  $\overline{x}$ = 0.58, s = 0.31
  Cpk = 0.45
- For Industry II : n = 27
  $\overline{x}$ = 0.59, s = 0.23
  Cpk = 0.61

In both the cases the process dispersion is high. The process improvement is required to reduce process variability. The revision of the specification requirement is needed because the relaxation shrinkage in weft direction may be less than the relaxation shrinkage in warp direction.

2.2.10 Composition - Polyester Content (%): Specification requirement - 67 ±2

- For Industry I: n = 44
  $\overline{x}$ = 67.84, s = 0.81
  Cp = 0.82
  K = 0.42
- For Industry II: n = 41
  $\overline{x}$ = 67.16, s = 1.34
  Cp = 0.5 K = 0.08

It is observed from the Figure 4 that the distribution of the characteristic in the Industry I is almost bell shaped whereas it is highly dispersed in the other case. The process variability although high is less in the former case. The process is off centered towards the right in the Industry I whereas the process off centering is almost negligible in the other. The shifting of process towards left may improve the matter the Industry I whereas the significant process improvement is needed to reduce variability in the Industry II in future bales.

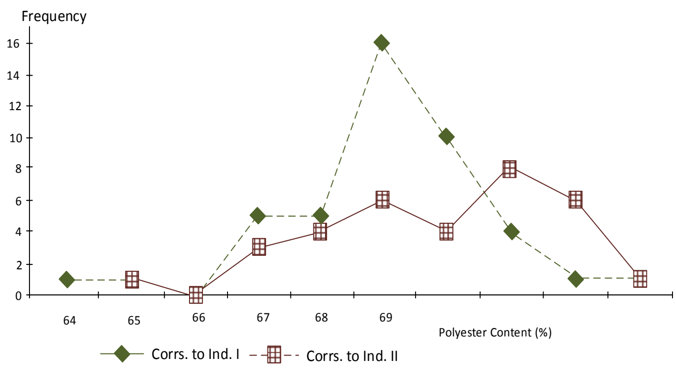

Fig.4. Distribution of Composition – Polyester Content (%)

2.2.11 Composition- Cotton Content (%) : Specification requirement - 33 ± 2

- For Industry I: n = 44
  $\overline{x}$ = 32.84, s = 1.34
  Cp = 0.82
  K = - 0.42
- For Industry II: n = 41
  $\overline{x}$ = 32.84, s = 1.34
  Cp = 0.5
  K = - 0.08

It is observed from the Figure 5 that the distribution of the characteristic in the Industry I in almost bell-shaped whereas it is highly dispersed in the other case. The process variability, although high, is less in the former case. The process is off-centered towards the left in the industry I whereas the process off-centering is almost negligible in the other. The shifting the process towards right may improve the matter in the Industry I whereas the significant process improvement is needed to reduce variability in the Industry II in future bales.

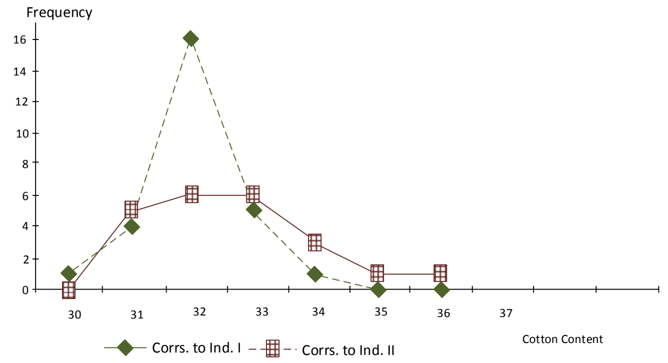

Fig.5. Distribution of Composition - Cotton Content (%)

***2.2.12 Water Solubility*:** Specification requirement - 1 % max.

- For Industry I : n = 44
  $\overline{x}$ = 0.45, s = 0.072
  Cpk = 2.54
- For Industry II: n = 41
  $\overline{x}$ = 0. 42, s = 0.065
  Cpk = 2.98

It is observed that the processes in both industries are capable. The process capability in the Industry II is somewhat higher than that of the Industry I.

2.2.13 pH Value of Aqueous Extract: Specification requirement - 6 to 9.5

- For Industry I : n = 49
  $\overline{x}$ = 7.04,s = 0.28
  Cp = 2.1
  K = - 0.12
- For Industry II: n = 41
  $\overline{x}$ = 6. 98, s = 0. 32
  C_p = 1.83
  K = - 0.15

It is observed from the Figure 6 that the distribution of the characteristic in both cases is bell shaped. The process capability in the Industry I is somewhat higher than that of the Industry II. In both cases the process is off- centered towards left. Since the processes in both cases are highly capable, the USL may be reduced to 8 because no observation lies beyond it.

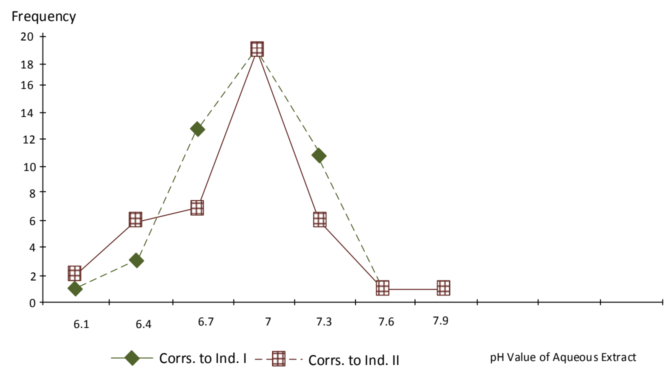

Fig.6. Distribution of pH Value of Aqueous Extract

2.3 Bivariate Process Capability Index and Relationship Between Breaking Strength (B.S.) and No. of Threads Per Dm in Warp and Weft directions Respectively

2.3.1 Warp B.S. Vs Ends/ dm

- For Industry I :
  Correlation Coefficient ρ = 0.34
  $P\hat{C}R_b$ = 0.17 i.e., the process is highly incapable Regression Equation
  y = 9.3x - 1208
- For Industry II :
  Correlation Coefficient ρ = 0.52
  $P\hat{C}R_b$ = 0.13 i.e., the process is highly incapable, Regression Equation
  y = 10.6x - 1609

Where x = Ends per dm and y = B.S. in warp direction.

From Regression Equations for specification limits for Warp B.S. i.e., 880 ± 5%, the values of Ends/dm for Industry I and Industry II come out to be 220 - 229 and 230 - 239 respectively against 260 ± 5% (247 to 273) specified. This is due to the fact that high values of Warp B.S. have been accepted for specified values of Ends/dm.

Similarly for specification limits for Ends/dm 260 ± 5% (247 to 273) the values of Warp B.S. for Industry I and Industry II come out to be 1089 -1331 and 1009 -1285 respectively. So, the difference in warp B.S. of two industries varies from 80 to 46 for specified limit for Ends/dm.

The derived regression equations cannot be recommended for further/standard application due to high values of Warp B.S. and low values of process capability indices of two correlated quality characteristics. The specified requirements may be revised / modified for warp B.S. and Ends per dm to maintain consistency.

2.3.2 Weft B.S. Vs Picks/dm.

- For Industry I
  Correlation Coefficient ρ = 0.27
  $P\hat{C}R_b$ = 0.073 i.e., the process is highly incapable. Regression Equation
  y = 3.4x + 214
- For Industry II
  Correlation Coefficient ρ = 0.5
  $P\hat{C}R_b$ = 0.075 i.e., the process is highly incapable.
  Regression Equation
  y = 6.9x-517

Where x = Picks per dm and y = B.S. in weft direction.

From Regression Equations, for specification limits for Weft B.S. i.e., 640 ± 5% (608 to 672), the values of Picks/dm for Industry I and Industry II come out to be 116 - 135 and 163 - 172 respectively against 190 ± 5% (180 to 200) specified. This is due to the fact that high values of Weft B.S. have been accepted for specified values of Picks/dm.

Similarly for specification limits for Picks/dm 190 ± 5% (180 to 200), the values of Weft B.S. for Industry I and Industry II come out to be 826 - 894 and 725 - 863 respectively. So, the difference in Weft B. S. of two industries varies from 101 to 31 for specified values of Picks/dm

In this case also, derived regression equations cannot be used for further/standard application due to high values of Weft

B.S. and low values of process capability indices of the two correlated quality characteristics. The specified requirements may be revised / modified for consistency.

2.4 Causes of Low Process Capability Measures

In cases of many quality characteristics of the cloth, low values of process capability measures have been observed. In general causes of low values are given below:

- High variability of the quality characteristics i.e., high skewness and platy-kurtosis in accepted bales.
- Deviation of the process mean from the target.
- In-homogeneity / non-uniformity of observations.
- Change and inadequacy of production processes.
- Testing / Measurement error.
- Conventional / unrevised specification.
- Uncontrollability of quality of grey cloth supplied by other sources.

2.5 Suggestions / Remedies for Improving Process Capability

- Control / revision of design / specification.
- Control on the quality of the grey cloth supplied by other sources.
- Utmost consideration of target.
- Regular monitoring, maintenance, and sustenance of the production processes.
- Control on Testing / measurement process.
- Use of Statistical Quality Control (SQC) methods.

References

[1] Lawrence C., Fibre to Yarn: Filament Yarn Spinning, Textile and Fashion**:** Materials, Design and Technology, 2015, chapter 10, pp. 213–253 (A chapter of a volume in Woodhead Publishing Series in Textiles)

[2] Wilson J., 1 – Fibres, yarns and fabrics: fundamental principles for the textile designer, Textile Design: Principles, Advances and Applications**,** 2011, pp., 3–30 (A chapter of volume in Woodhead Publishing Series in Textiles)

[3] Merati A. A., Semnani D., 18 – Textile quality evaluation by image processing and soft computing techniques, soft computing in textile Engineering, 2011, pp. 490–523(A chapter of volume in Woodhead Publishing Series in Textiles)

[4] Das A., 3 – Testing and statistical quality control in textile manufacturing**,** Process Control in Textile Manufacturing, 2013, pp 41–78(A chapter **of** a volume in Woodhead Publishing Series in Textiles)

[5] Kane V.E.,*Process capability indices*, Journal of Quality Technology, 1986, vol. 18, pp. 41-52, corrigenda 265

[6] Chan L.K., Cheng S.W., Spiring F.A., *A new measure of process capability index* C_{pm}, Journal of Quality Technology, 1988, vol. 30, pp. 162-175

[7] Taguchi G., H Siang T.C., *A Tutorial on Quality Control and Assurance – the Taguchi Methods*, Unpublished presentation given at the Annual Meeting of the American Statistical Association Las Vegas LV, 1985

[8] Mukherjee S.P., Singh N.K., *A Process capability index for two correlated quality characteristics*, *IAPQR* Transactions, 1993, vol. 18(2), pp. 49-55.