TMMOB Tekstil Mühendisleri Odası
UCTEA Chamber of Textile Engineers
Tekstil ve Mühendis
Journal of Textiles and Engineer

Yıl (Year) : 2026/1
Cilt (Vol) : 33
Sayı (No) : 141

Araştırma Makalesi / Research Article

OPTIMIZING YARN QUALITY THROUGH CLEANING INTERVENTIONS: EFFECTS OF WIRE CYLINDER AND STATIONARY FLAT MAINTENANCE ON NEPS COUNT AND UNEVENNESS PERCENTAGE (U%) IN CARDED SLIVERS

Dedy HARIANTO*[1]
Bagus PRADITA[1]
Hamdan S. BINTANG[1]
Hendri PUJIANTO[1]
[1]Akademi Komunitas Industri Tekstil dan Produk Tekstil Surakarta, Indonesia

Gönderilme Tarihi / Received: 11.03.2025
Kabul Tarihi / Accepted: 20.02.2026

***ABSTRACT*:** Maintaining yarn quality is crucial in textile manufacturing, where neps count and sliver unevenness percentage (U%) significantly impact production consistency and fabric performance. This study evaluates the effect of cleaning wire cylinders and stationary flats on neps count and U% in carded slivers, providing a cost-effective alternative to advanced predictive maintenance techniques. Using a randomized experimental design, measurements were conducted on two production lines (B2 and B3) before and after cleaning interventions. Neps count and U% were assessed using the Advanced Fiber Information System (AFIS) and Uster Tester, respectively. Statistical analysis, including t-tests and effect size calculations, revealed significant reductions in neps count (B2: 76.08 to 39.50; B3: 88.00 to 40.23) and U% (B2: 7.19% to 4.34%; B3: 8.27% to 4.25%), meeting industry benchmarks. The findings demonstrate that routine cleaning enhances fiber alignment, reduces defects, and improves production consistency without the high costs of predictive maintenance systems. This study highlights the importance of structured maintenance practices and provides a foundation for optimizing cost-effective and sustainable textile manufacturing processes.

Keywords: Yarn quality, Neps count, Unevenness percentage (U%), Carding machine maintenance

TEMİZLİK MÜDAHALELERİYLE İPLİK KALİTESİNİN OPTİMİZASYONU: TEL SİLİNDİR VE SABİT DÜZLEMLERİN BAKIMININ TARAKLANMIŞ ŞERİTTE NEPS SAYISI VE DÜZGÜNSÜZLÜK YÜZDESİ (U%) ÜZERİNE ETKİLERİ

***ÖZ*:** Tekstil üretiminde iplik kalitesinin korunması büyük önem taşımakta olup, neps sayısı ve şerit düzgünsüzlük yüzdesi (U%) üretim tutarlılığı ve kumaş performansı üzerinde önemli bir etkiye sahiptir. Bu çalışma, tel silindirlerin ve sabit tarakların temizlenmesinin neps sayısı ve U% üzerindeki etkisini değerlendirerek, ileri düzey kestirimci bakım tekniklerine maliyet etkin bir alternatif sunmaktadır. Rastgele deneysel tasarım kullanılarak, iki üretim hattında (B2 ve B3) temizleme işlemleri öncesinde ve sonrasında ölçümler gerçekleştirilmiştir. Neps sayısı ve U% sırasıyla Advanced Fiber Information System (AFIS) ve Uster Tester cihazları ile değerlendirilmiştir. t-testi ve etki büyüklüğü hesaplamaları gibi istatistiksel analizler, neps sayısında (B2: 76.08'den 39.50'ye; B3: 88.00'den 40.23'e) ve U% değerinde (B2: %7.19'dan %4.34'e; B3: %8.27'den %4.25'e) anlamlı düşüşler olduğunu ortaya koymuş ve bu sonuçlar sektör standartlarını karşılamıştır. Bulgular, rutin mekanik temizliğin lif yönlenmesini iyileştirdiğini, hataları azalttığını ve tahmine dayalı bakım sistemlerinin yüksek maliyetleri olmadan üretim düzgünlüğünü artırdığını göstermektedir. Bu çalışma, planlı ve sistematik bakım uygulamalarının önemini vurgulayarak, maliyet etkin ve sürdürülebilir tekstil üretim süreçlerinin optimize edilmesine yönelik bir temel sağlamaktadır.

Anahtar Kelimeler: İplik kalitesi, Neps sayısı, Düzgünsüzlük yüzdesi (U%), Tarak makinesi bakımı

***Sorumlu Yazarlar/Corresponding Authors:** *dedy_mits@yahoo.com*
DOI: *https://doi.org/10.7216/teksmuh.1655377* *www.tekstilvemuhendis.org.tr*

1. INTRODUCTION

Carding is an important operation in textile manufacturing that combines fibers into slivers, a key determinant of yarn quality [1]. In particular, defects like neps count acting with sliver unevenness percentage (U%), lower production consistency and increase subsequent yarn breakage rates later, as [2] and [3] point out. Neps are small entanglements of fibers that have an adverse effect on the quality of cotton yarns and fabrics. These defects may lower product value and adversely affect the economics of the textile sector [4]. Sliver unevenness is defined as the irregularity in the linear density of a sliver; it is an important contributing factor to the quality of the final yarn [5]. Poor fixed-wire maintenance and maintenance of flat stationary mechanisms contribute significantly to increased neps and sliver unevenness [6]. Research shows that optimizing cylinder speed and flat position improves sliver uniformity, reduces fiber damage, and enhances yarn quality [7]. However, advanced predictive maintenance techniques are unaffordable for many Small and Medium-sized Enterprises (SMEs) due to financial constraints [5, 8].

Proper maintenance enhances sliver quality by reducing neps count and unevenness, thus maintaining consistent production [9]. Predictive technologies in equipment fault monitoring provide timely detection, and thereby improve operational reliability [10]. These advanced technologies are costly, requiring significant investments in specialized equipment, skilled staff, and facilities, which puts them out of reach for small producers [11].

Cleaning is a simple, low-cost maintenance approach that improves fiber alignment and sliver quality during operation. Previous research has shown that cleaning is effective in removing fiber obstructions, thus increasing alignment and minimizing defects [12, 13]. Unlike many studies that focus only on surface-level fiber debris removal [14-16], this study systematically quantifies the impact of mechanical cleaning (rather than surface cleaning alone) on key textile quality parameters, specifically neps count and yarn evenness. By incorporating statistical analyses, this study provides a more precise evaluation of mechanical cleaning's effectiveness, bridging a gap in the existing literature. This study was conducted on two representative carding machines located in section B of the production facility, with evaluations performed both before and after routine cleaning maintenance.

Although research on static flats and wire cylinders has been developed [17, 18], studies often do not consider the impact of humidity and temperature on fiber behavior during cleaning [19, 20], and standard operating procedures vary by machine models, presenting significant implementation barriers in factory settings [21].

Maintaining wire cylinders and stationary flats improves sliver quality and supports cost-effective production [22, 23]. Sensor-based predictive technologies help minimize machine failures and fiber waste [24, 25]. However, these strategies have advanced infrastructural demands, and therefore tend to be less available to SMEs (Small and Medium-sized Enterprises). The evidence suggests that cleaning interventions, although less resource-intensive, can yield improvements in sliver quality with potential downstream yarn benefits.

Small-scale producers often prioritize eco-friendly technologies because of limited resources for technological development [26]. Synchronized procedures for each production facility facilitate scalability to achieve a uniform sliver quality [27]. Integration of environmental considerations in frameworks such as optimizing flat speeds and cylinder wear aligns with global sustainability standards [28, 29]. This study thus provides the basis for structured and sustainable maintenance interventions, taking into account both economic and environmental challenges [30, 31].

The impact of cleaning wire cylinders and stationary flats on neps count and U% is analyzed to evaluate their effect on fiber processing efficiency and product quality. Cleanliness of these components is of paramount importance for the reduction of fiber damage [32] and for preventing the formation of neps count [33]. Previous studies have emphasized maintaining carding machines to ensure higher quality in fiber processing. For example, [34] highlights optimizations for reduced carding speeds that minimize such defects, and show that maintenance through cleaning significantly improves sliver uniformity. Clean working conditions allow carding to function properly by facilitating better alignment of fibers and thus minimizing defects [35].

The effectiveness of cleaning interventions was quantitatively evaluated by comparing pre- and post-cleaning measurements using pre-specified statistical analyses (e.g., Shapiro–Wilk and independent t-tests).

Although several previous studies have shown that maintenance actions such as adjusting flat speed or implementing predictive maintenance systems can improve sliver and yarn quality [5, 7, 10], few studies have quantitatively evaluated the impact of routine mechanical cleaning on sliver/yarn quality. Existing literature tends to emphasize machine parameter optimization or automated technologies [2, 3, 8]. These approaches often require high-cost equipment and technical infrastructure that are not accessible to many small and medium-sized enterprises (SMEs) [5, 11, 24].

This study provides a statistically validated, empirical analysis of manual cleaning interventions applied to wire cylinders and stationary flats. It focuses on two key indicators of sliver quality, namely neps count and unevenness percentage (U%), using standardized testing with AFIS (Uster® AFIS Pro 2) and Uster® Tester instruments under controlled environmental conditions in actual production lines [12, 13, 33].

The objective of this research is to address this gap by presenting an effective, affordable, and replicable maintenance strategy. The findings are intended to serve as a reference for facilities with limited access to advanced predictive maintenance tools, particularly SMEs, to maintain consistent sliver quality through structured cleaning interventions, with potential downstream benefits for yarn quality [25, 31, 34].

2. RESEARCH METHOD

This study investigates the effect of cleaning wire cylinders and stationary flats on the neps count and unevenness percentage (U%) of carded slivers in a textile production facility. The experimental work was conducted using two Carding Ming Cheng machines (lines B2 and B3) selected from a total of eight identical machines operating within the facility. These two lines were chosen because they represent typical operational conditions, with no significant differences in machine age, maintenance history, or operational parameters compared to the other lines. Prior to carding, fibers were processed using standard opening and blending equipment in accordance with facility SOPs to ensure uniform feedstock.

All cleaning and maintenance procedures in this study were carried out according to the official factory maintenance schedule for January 2025. The schedule outlines the planned scouring and cleaning activities for both blowing and carding machines, including specific machine lines and the rotation of daily tasks. Each maintenance activity is coordinated by technical supervisors and approved by plant management to ensure consistency and compliance with industrial standards. This approach guarantees that the interventions implemented in the study reflect standard operational procedures and actual practices in the production environment.

Carding machine settings were selected based on standard operating procedures and QC benchmarks that reflect the most prevalent operational conditions in SME-scale spinning mills. The selection was further justified by prior industry observations indicating that these settings maximize both production efficiency and yarn quality. The rationale for focusing on these machine settings and fiber properties stems from previous industrial observations, which have shown that the cleaning of wire cylinders and stationary flats plays a significant role in reducing neps formation and sliver unevenness, thus directly enhancing the final yarn quality. The detailed operational settings for both carding machines are summarized in Table 1.

Both carding machines, manufactured in Taiwan in 2009 and fitted with Geron wire. Each machine was equipped with six rear and three front stationary flats. Although the machines are capable of running at production speeds between 90 and 150 meters per minute, for the purposes of this study, both machines were consistently operated at a standardized speed of 110 meters per minute to ensure comparability of results. All operational parameters were strictly controlled and maintained constant throughout the experimental period.

The fiber processed in this study was 100% cotton, sourced from [USA, 2024]. Fiber properties were determined using a Uster High Volume Instrument (HVI) following standard industry protocols. All values reported represent the mean ± standard deviation from three independent samples. The measured parameters, together with industry benchmark values for reference, are presented in Table 2.

Table 1. Main operational parameters of the carding machine used in this study.

Parameter	Value
Feed rate/output	110 m/min
Sliver weight	4.0 g/m
Licker-in (taker-in) speed	860 rpm
Cylinder speed	410 rpm
Flat speed	0.25 m/min (250 mm/min)
Doffer speed	45 rpm
Cylinder-flat setting	0.30 mm
Cylinder-doffer setting	0.13 mm
Feed plate–licker-in gap	0.50 mm
Draft ratio	1.8
Machine efficiency	90%

Table 2. Fiber Properties of 100% Cotton (Measured by Uster HVI)

Property	Value (mean ± SD)	Unit
Spinning Consistency Index (SCI)	122.6 ± 1.7	–
Micronaire	3.91 ± 0.04	μg/inch
Upper half mean length (UHML)	29.15 ± 0.22	mm
Maturity Index (MI)	0.89 ± 0.02	–
Uniformity Index (UI)	78.4 ± 0.5	%
Short Fiber Index (SFI)	7.1 ± 0.3	%
Strength	32.1 ± 0.7	g/tex
Elongation	7.4 ± 0.2	%
Reflectance (Rd)	76.1 ± 0.5	–
Yellowness (+b)	8.6 ± 0.3	–

A representative photograph of the carding machine (Figure 1) and a technical schematic (Figure 2) are provided to illustrate the actual equipment and the specific locations where the cleaning interventions were applied in this study. In addition, Figures 3 and 4 show the condition of the wire cylinder and the stationary flats, respectively, before the cleaning process, thereby emphasizing the level of contamination that was addressed.

Figure 1. Photograph of the Ming Cheng carding machine (B2/B3) used in the study, showing the sliver drums and operator interface in the production facility.

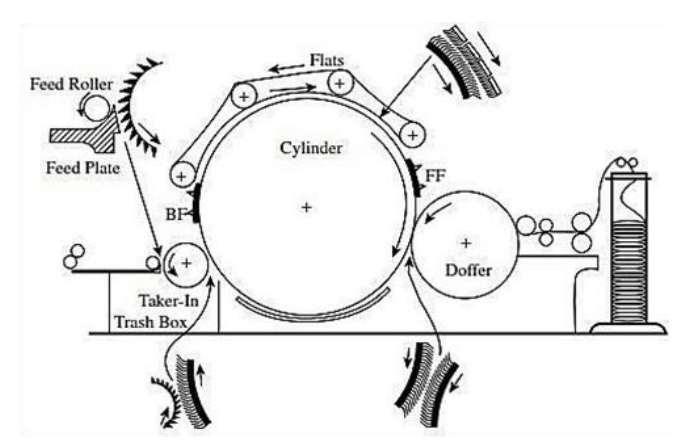

Figure 2. Schematic diagram of a typical carding machine, illustrating key components relevant to the study. The main cleaning intervention in this research was focused on the wire cylinder and stationary flats, as indicated in the diagram. BF = Back Flats; FF = Front Flats.

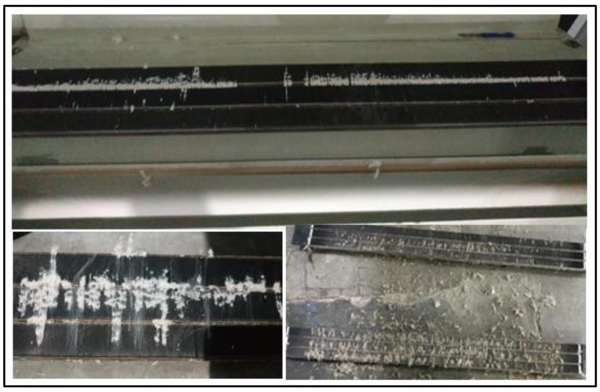

Figure 3. Surface contamination on the wire cylinder prior to cleaning. The accumulation of fiber residues and other particulate matter is clearly visible along the wire lines, potentially hindering carding efficiency and fiber individualization.

Figure 4. Dirty surface of the stationary flats before cleaning. Significant deposits of waste fibers and embedded impurities can be observed, which may interfere with fiber transfer and lead to quality degradation in sliver output.

Sample size determination was performed using a priori power analysis, resulting in the collection of 160 samples per production line (B2 and B3): 40 measurements each for neps count and U% before and after cleaning. Samples were systematically and randomly collected under tightly controlled environmental conditions (23 ± 2°C; 55 ± 5% RH). Temperature and humidity were continuously monitored using an AM2301 digital temperature and hygrometer, with all deviations from the required range corrected using an HVAC and automated humidifier–dehumidifier system [36]. To prevent sampling bias, machine selection and sampling order were randomized, and the fiber composition was kept constant across all trials.

After collection, all samples were prepared and stored according to SNI 08-0261-1989 and SNI 08-0262-1989, at 20–25°C and 65–70% relative humidity [37], [38]. This ensured that fiber properties and sample integrity were maintained prior to measurement.

Neps content was measured using the AFIS (Uster® AFIS Pro 2) instrument. For each test, a sliver sample of approximately 0.5 grams was gently stretched to a length of 28–30 cm. Handling was minimized to prevent disruption of existing neps. Each sample underwent five partial test runs, completed within a two-minute timeframe, resulting in a total analyzed mass of two grams per sample.

Sliver evenness (U%) was assessed using the Uster® Tester instrument, operating at a fixed test speed of 50 meters per minute. Each sliver sample was evaluated over a minimum length of 50 meters. For each production condition, ten replicate readings were obtained from randomly selected sliver cans. This sampling approach ensured that the results were statistically representative and reproducible across all experimental conditions.

The same testing protocol was repeated after the cleaning interventions, using the identical instruments, sample preparation procedures, test lengths, and environmental conditions. This consistency ensures that any observed differences in neps count or U% can be attributed solely to the cleaning treatments rather than measurement variability.

Both AFIS and Uster Tester instruments were cross-calibrated before data collection, following the manufacturer's protocols and standard laboratory practices. In this study, cross-calibration refers to the process where both instruments were adjusted and validated using the same manufacturer-certified reference samples (with known neps count and U% values). The measurements from each device were compared, and calibration adjustments were performed if discrepancies greater than ±1% were observed. Quality control procedures ensured that replication reliability was maintained within a 5% variation threshold across all independent measurements. All calibration and quality control steps were performed by trained laboratory staff in accordance with established procedures.

However, due to laboratory data management policy at the time of measurement, detailed calibration records are not available for external sharing. We acknowledge this limitation and have implemented improved data management procedures in subsequent studies to ensure full traceability. We confirm that all reported results meet internal quality control standards, and that the calibration process followed accepted protocols for instrument validation and measurement reliability. This approach ensures that neps count and U% values measured by AFIS and Uster Tester are directly comparable, providing reliable and consistent results across both instruments.

Cleaning was performed without the use of chemicals, relying solely on mechanical methods to remove fiber accumulation. The wire cylinder was cleaned using a soft-bristle brush and a lint-free cloth to dislodge and remove trapped fibers and debris, as shown in Figure 5. Similarly, the stationary flats were manually cleaned using lint-free cloths to eliminate residual dust and fiber particles, as illustrated in Figure 6. These tools were selected to ensure effective cleaning without causing surface damage. Each cleaning session lasted approximately 20 minutes per machine, and all tests were conducted under identical environmental conditions before and after cleaning to ensure direct comparability [39].

Figure 5. Photograph showing the manual cleaning process of the wire cylinder using a lint-free cloth and soft-bristle brush, as performed during scheduled maintenance.

Figure 6. Manual cleaning of the stationary flats using a lint-free cloth to remove adhered fiber residues and dust. This method was used to ensure effective removal of contaminants while preserving the surface integrity.

Reference standards for neps count and U% were obtained from the Quality Control (QC) department of the company where this research was conducted. These thresholds (<46 neps/gram and <4.5% U%) align with recent industry benchmarks and internal company QC criteria [40].

All statistical analyses were performed using SPSS version 27. Data normality was evaluated using the Shapiro–Wilk test. For data meeting the normality assumption, independent t-tests were applied to compare pre- and post-cleaning measurements. For non-normally distributed data, the Mann–Whitney U test was used.

Normality testing was essential to determine whether the data distribution met the assumptions required for parametric analysis. By applying the unpaired t-test (or Mann–Whitney U test for non-normal data), the study was able to rigorously assess whether observed differences between pre- and post-cleaning conditions were statistically significant and attributable to the intervention rather than random variation.

To assess practical significance, effect size indices, namely Cohen's d (standardized mean difference), Hedges' g (bias correction for small samples), and Glass's delta (for unequal variances), were calculated for all outcomes. Standard benchmarks (d = 0.2, 0.5, 0.8) were used to interpret effect sizes. All analyses were conducted at a significance level of $\alpha = 0.05$.

Results were collected in a variety of forms known as descriptive statistics, mean, median, or even standard deviation [41]. The changes in neps content and U% uniformity were computed according to the aforementioned equations.

$$\Delta Neps = Neps_{before} - Neps_{after}$$

and

$$\Delta U\% = U\%_{before} - U\%_{after}$$

Line graphs created in Excel illustrate how cleaning enhances sliver quality [42]. This way, the designed approach empowers the investigator to make a sound and thorough evaluation of the impact of the cleaning process on neps count and U%, and hence provides important recommendations on the mechanisms that can be improved in view of cleaning maintenance for the carding machine [43].

3. RESULT

3.1 Neps Count

3.1.1 Descriptive Statistics

Neps count values for Line B2 and Line B3, measured before and after cleaning, are provided in Table 3.

The terminologies applied in this study are defined as follows: NepsB2Before and NepsB2After indicate the neps count measured in Line B2 before and after the cleaning intervention, while NepsB3Before and NepsB3After correspond to neps count values obtained from Line B3 under the same conditions.

Table 3. The neps count data for Line B2 and Line B3 before and after cleaning.

	LINE B2				LINE B3			
	Before Cleaning	After Cleaning	ΔNeps	standard	Before Cleaning	After Cleaning	ΔNeps	standard
1	78	42	36	46	91	40	51	46
2	76	37	39	46	88	42	46	46
3	79	39	40	46	88	44	44	46
4	75	43	32	46	90	39	51	46
5	73	38	35	46	88	43	45	46
6	76	43	33	46	86	37	49	46
7	79	40	39	46	87	41	46	46
8	75	41	34	46	89	39	50	46
9	72	42	30	46	88	43	45	46
10	79	37	42	46	89	38	51	46
11	80	38	42	46	90	44	46	46
12	78	39	39	46	91	40	51	46
13	79	40	39	46	87	39	48	46
14	78	39	39	46	90	41	49	46
15	74	36	38	46	85	37	48	46
16	77	42	35	46	87	43	44	46
17	77	41	36	46	86	38	48	46
18	74	38	36	46	88	42	46	46
19	71	40	31	46	91	40	51	46
20	80	37	43	46	87	39	48	46
21	74	39	35	46	89	41	48	46
22	73	43	30	46	90	38	52	46
23	80	38	42	46	85	43	42	46
24	72	41	31	46	88	37	51	46
25	75	42	33	46	86	42	44	46
26	77	40	37	46	87	39	48	46
27	73	39	34	46	89	41	48	46
28	72	37	35	46	90	38	52	46
29	76	38	38	46	85	41	44	46
30	75	36	39	46	89	37	52	46
31	71	42	29	46	88	40	48	46
32	78	41	37	46	86	39	47	46
33	81	40	41	46	89	41	48	46
34	75	39	36	46	85	38	47	46
35	76	38	38	46	87	42	45	46
36	77	36	41	46	87	42	45	46
37	75	41	34	46	88	40	48	46
38	77	42	35	46	89	40	49	46
39	77	37	40	46	91	41	50	46
40	79	39	40	46	86	40	46	46
average	76.08	39.50	36.58	46	88.00	40.23	47.78	46

Table 4. Summary of mean, median, variance, and standard deviation for neps count in Line B2 and Line B3 before and after cleaning.

Metric	**Pre-Cleaning Mean (±SE)**	**Post-Cleaning Mean (±SE)**	**Median (Pre → Post)**	**Variance (Pre → Post)**	**Std. Deviation (Pre → Post)**
Neps (Line B2)	76.08 (±0.43)	39.50 (±0.33)	76.00 → 39.00	7.25 → 4.36	2.69 → 2.09
Neps (Line B3)	88.00 (±0.28)	40.23 (±0.32)	88.00 → 40.00	3.23 → 3.97	1.80 → 1.99

Descriptive statistics indicate a substantial reduction in neps count after cleaning. In Line B2, mean neps count decreased from 76.08 to 39.50. In Line B3, neps count dropped from 88.00 to 40.23, meeting industry standards.

After cleaning, the neps count was substantially reduced in both lines, with Line B2 decreasing from 76.08 to 39.5 and Line B3 from 88 to 40.23. These values are well below the industry threshold of 46 neps, demonstrating the impact of cleaning based on 40 AFIS measurements for each condition.

3.1.2 Normality Test for Neps Count

Normality of neps count data was assessed using Shapiro-Wilk and Kolmogorov-Smirnov tests, as parametric testing requires normally distributed data [44], [45]. The test results are reported in Table 5.

The Shapiro-Wilk test showed all p-values for neps count were above 0.05, indicating normality in each group. Borderline results were observed for Line B2 after cleaning ($p = 0.054$) and Line B3 before cleaning ($p = 0.053$), but these values still support the null hypothesis. The data thus satisfy the assumption for parametric tests [46].

3.1.3 Unpaired t-Test for Neps Count

Neps count before and after cleaning in Lines B2 and B3 were compared as independent groups using the unpaired t-test, since samples were not paired. It is important to note that the before and after cleaning yarn samples were not identical, although both originated from the same production lines. This approach determines if cleaning produces statistically significant differences in neps count between conditions [47, 48].

Statistical significance of cleaning effects on neps count was evaluated using an independent samples t-test for each group. Results for neps count comparisons are summarized in Table 6.The independent samples t-test revealed a highly significant reduction in neps count after cleaning for both lines. All p-values were below 0.001, and the mean difference was substantial: 36.58 for Line B2 and 47.78 for Line B3. Large t-values and narrow confidence intervals confirm robust statistical significance.

3.1.4 Effect Size and Practical Significance for Neps Count

Effect-size estimates for neps counts were very large: Cohen's d = 2.41 (B2) and 2.76 (B3), with corresponding Hedges' g = 2.38 and 2.72, and Glass's Δ = 2.09 and 2.43. These magnitudes far exceed the conventional benchmark for a large effect ($d \approx 0.80$), indicating a substantial post-cleaning reduction in neps.

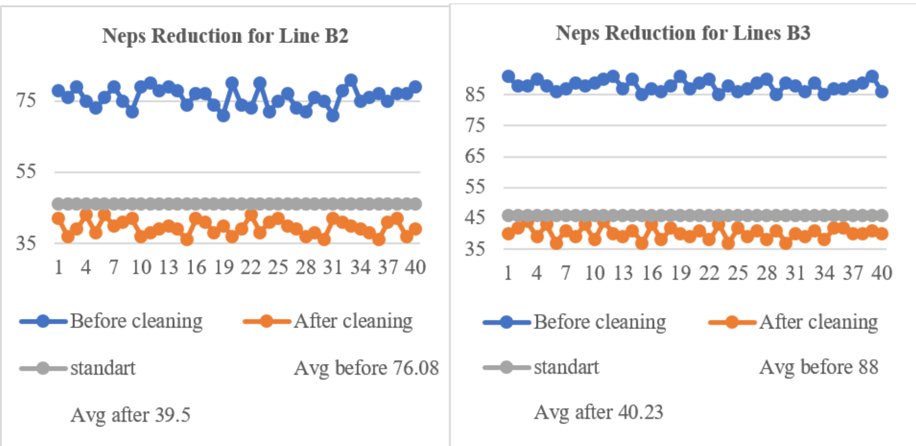

Figure 7. Neps Reduction (Line B2 and Line B3) Before and After Cleaning

Table 5. Assessment of data normality for neps count in Line B2 and Line B3, before and after cleaning, using Shapiro-Wilk and Kolmogorov-Smirnov tests.

Metric	Kolmogorov-Smirnov Statistic	Kolmogorov-Smirnov Sig.	Shapiro-Wilk Statistic	Shapiro-Wilk Sig.
Neps Line B2 Before Cleaning	0.109	0.2	0.965	0.245
Neps Line B2 After Cleaning	0.12	0.154	0.946	0.054
Neps Line B3 Before Cleaning	0.111	0.2	0.946	0.053
Neps Line B3 After Cleaning	0.106	0.2	0.955	0.114

Table 6. Independent samples t-test results for neps count before and after cleaning in Line B2 and Line B3.

Metric	t	df	Sig. (2-tailed)	Mean Difference	95% CI (Lower-Upper)
Neps B2	67.89	78	<0.001	36.58	35.50 – 37.64
Neps B3	112.57	78	<0.001	47.78	46.93 – 48.62

Table 7. Effect size and practical significance analysis for neps count before and after cleaning in Line B2 and Line B3.

Metric	Cohen's d	Hedges' g	Glass's Δ
Neps B2	2.41	2.38	2.09
Neps B3	2.76	2.72	2.43

Table 8. U% data for Line B2 and Line B3 before and after cleaning.

	LINE B2				LINE B3			
	Before Cleaning	After Cleaning	ΔU%	standard	Before Cleaning	After Cleaning	ΔU%	standard
1	7.01	4.25	2.76	4.5	8.2	4.31	3.89	4.5
2	7.26	4.3	2.96	4.5	8.44	4.29	4.15	4.5
3	6.89	4.35	2.54	4.5	7.99	4.19	3.8	4.5
4	7.25	4.32	2.93	4.5	8.33	4.21	4.12	4.5
5	7.35	4.38	2.97	4.5	8.09	4.25	3.84	4.5
6	7.17	4.29	2.88	4.5	8.15	4.23	3.92	4.5
7	6.91	4.32	2.59	4.5	8.33	4.3	4.03	4.5
8	7.32	4.31	3.01	4.5	8.26	4.24	4.02	4.5
9	7.48	4.39	3.09	4.5	8.61	4.25	4.36	4.5
10	7.11	4.37	2.74	4.5	8.1	4.23	3.87	4.5
11	7.29	4.29	3	4.5	8.47	4.28	4.19	4.5
12	7.22	4.39	2.83	4.5	8.25	4.26	3.99	4.5
13	6.97	4.35	2.62	4.5	8.4	4.22	4.18	4.5
14	7.44	4.4	3.04	4.5	8.36	4.31	4.05	4.5
15	7.28	4.28	3	4.5	8.22	4.22	4	4.5
16	7.09	4.36	2.73	4.5	8.18	4.26	3.92	4.5
17	6.92	4.34	2.58	4.5	7.92	4.19	3.73	4.5
18	7.41	4.33	3.08	4.5	8.32	4.22	4.1	4.5
19	7.15	4.41	2.74	4.5	8.21	4.22	3.99	4.5
20	7.4	4.31	3.09	4.5	8.48	4.27	4.21	4.5
21	7.27	4.27	3	4.5	8.17	4.24	3.93	4.5
22	7.03	4.34	2.69	4.5	8.23	4.2	4.03	4.5
23	7.19	4.41	2.78	4.5	8.29	4.19	4.1	4.5
24	7.04	4.33	2.71	4.5	8.31	4.28	4.03	4.5
25	7.22	4.43	2.79	4.5	8.35	4.24	4.11	4.5
26	7.18	4.31	2.87	4.5	8.16	4.26	3.9	4.5
27	7.38	4.36	3.02	4.5	8.29	4.3	3.99	4.5
28	7.01	4.33	2.68	4.5	8.19	4.23	3.96	4.5
29	7.06	4.36	2.7	4.5	8.37	4.29	4.08	4.5
30	7.22	4.35	2.87	4.5	8.19	4.24	3.95	4.5
31	7.21	4.3	2.91	4.5	8.34	4.27	4.07	4.5
32	7.31	4.37	2.94	4.5	8.35	4.29	4.06	4.5
33	7.34	4.28	3.06	4.5	8.27	4.27	4	4.5
34	7.23	4.4	2.83	4.5	8.38	4.2	4.18	4.5
35	7.05	4.34	2.71	4.5	8.11	4.24	3.87	4.5
36	7.1	4.37	2.73	4.5	8.42	4.19	4.23	4.5
37	7.3	4.3	3	4.5	8.24	4.21	4.03	4.5
38	7.18	4.39	2.79	4.5	8.3	4.28	4.02	4.5
39	7.13	4.37	2.76	4.5	8.41	4.23	4.18	4.5
40	7.16	4.39	2.77	4.5	8.2	4.22	3.98	4.5
average	7.19	4.34	2.84	4.5	8.27	4.25	4.03	4.5

3.2 Unevenness Percentage (U%)

3.2.1 Descriptive Statistics

The unevenness percentage (U%) results for Line B2 and Line B3, both prior to and following cleaning, are summarized in Table 8.

For clarity, UB2Before and UB2After represent the unevenness percentage (U%) for Line B2 prior to and following cleaning. Similarly, UB3Before and UB3After refer to the U% values in Line B3 before and after the cleaning process.

Descriptive statistics show a marked reduction in U% after cleaning. In Line B2, U% decreased from 7.19 to 4.34. In Line B3, U% declined from 8.27 to 4.25, meeting the industry standard.

Cleaning led to a marked improvement in unevenness percentage, as U% dropped from 7.19 to 4.34 in Line B2 and from 8.27 to 4.25 in Line B3. Both results satisfy the <4.5% standard, and a notable reduction in variance further indicates enhanced uniformity, with all data obtained from 40 Uster Tester trials per setting.

Table 9. Overview of central tendency and dispersion statistics for unevenness percentage (U%) in Line B2 and Line B3, comparing pre- and post-cleaning conditions.

Metric	Pre-Cleaning Mean (±SE)	Post-Cleaning Mean (±SE)	Median (Pre → Post)	Variance (Pre → Post)	Std. Deviation (Pre → Post)
U% (Line B2)	7.19 (±0.02)	4.34 (±0.01)	7.20 → 4.35	0.022 → 0.002	0.15 → 0.04
U% (Line B3)	8.27 (±0.02)	4.25 (±0.01)	8.28 → 4.24	0.018 → 0.001	0.14 → 0.04

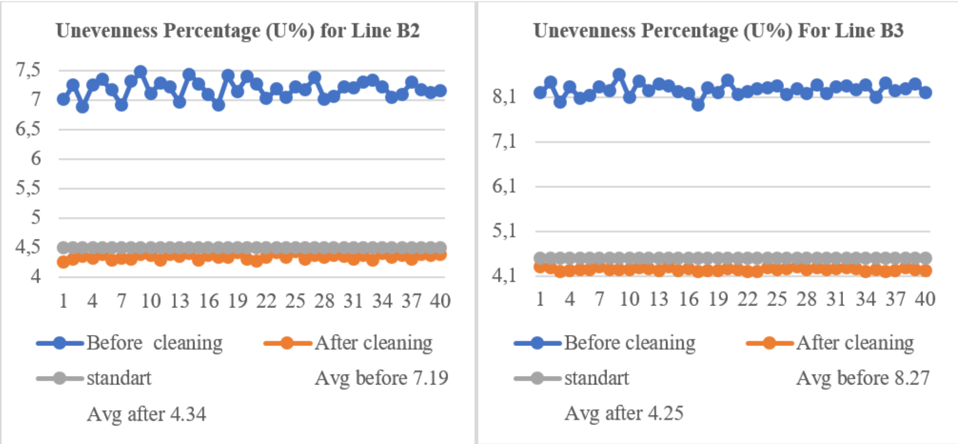

Figure 8. Unevenness Percentage (U%) (Line B2 and Line B3) Before and After Cleaning

3.2.2 Normality Assessment for Unevenness Percentage (U%)

For U% data, normality was also evaluated using Shapiro-Wilk and Kolmogorov-Smirnov tests to ensure the validity of subsequent parametric analyses [41], [45]. Detailed results are presented in Table 10.

For U%, all Shapiro-Wilk p-values ranged from 0.116 to 0.964, indicating strong evidence of normal distribution. Since all values exceeded 0.05, the null hypothesis of normality was not rejected, confirming the data are appropriate for t-test analysis [46].

3.2.3 Independent t-Test for Unevenness Percentage (U%)

U% values in Lines B2 and B3, measured before and after cleaning, were analyzed as independent samples. The independent t-test was used to assess whether cleaning significantly affected U% across groups [47], [48].

For U%, statistical differences before and after cleaning were also assessed using the independent t-test. The summary of U% results appears in Table 11.

For U%, the independent t-test comparing pre-cleaning versus post-cleaning within each production line also showed highly significant decreases after cleaning, with p-values <0.001. The mean difference was 2.85 for Line B2 and 4.03 for Line B3. The strong t-values and tight confidence intervals further support the reliability of these results.

3.2.4 Effect Size and Practical Significance for Unevenness Percentage (U%)

For U%, effect sizes ranged from 3.2 to 3.6 across both B2 and B3 lines, indicating an extremely strong practical impact. These values far exceed the threshold of 0.80 for a large effect, confirming that the cleaning intervention had a pronounced and highly meaningful effect on improving sliver evenness. The magnitude of these results highlights the significant benefits of routine cleaning in industrial production settings.

Table 10. Evaluation of normality for unevenness percentage (U%) data in Line B2 and Line B3, before and after cleaning, based on Shapiro-Wilk and Kolmogorov-Smirnov test results.

Metric	Kolmogorov-Smirnov Statistic	Kolmogorov-Smirnov Sig.	Shapiro-Wilk Statistic	Shapiro-Wilk Sig.
U% Line B2 Before Cleaning	0.059	0.2	0.984	0.841
U% Line B2 After Cleaning	0.08	0.2	0.982	0.748
U% Line B3 Before Cleaning	0.058	0.2	0.989	0.964
U% Line B3 After Cleaning	0.111	0.2	0.955	0.116

Table 11. Independent t-test results comparing U% before and after cleaning in Line B2 and Line B3.

Metric	t	df	Sig. (2-tailed)	Mean Difference	95% CI (Lower-Upper)
U% B2	115.3	78	<0.001	2.85	2.79 – 2.90
U% B3	182.18	78	<0.001	4.03	3.98 – 4.07

Table 12. Effect size and practical significance analysis for unevenness percentage (U%) before and after cleaning in Line B2 and Line B3.

Metric	Cohen's d	Hedges' g	Glass's Δ
U% B2	3.22	3.19	2.89
U% B3	3.61	3.57	3.2

4. DISCUSSION

The results show that mechanical cleaning of the stationary flat and wire cylinder led to significant improvements in sliver quality for both lines. In Line B2, neps count decreased from 76.08 to 39.50 and U% from 7.19 to 4.34. In Line B3, neps count dropped from 88.00 to 40.23 and U% from 8.27 to 4.25. These findings confirm that mechanical cleaning effectively reduces fiber imperfections and enhances sliver evenness, with potential downstream benefits for yarn quality [34].

The post-cleaning decreases in variability, as determined by variances and standard deviations, indicate consistency regarding sliver production. Such consistency is crucial for maintaining high-quality standards and minimizing defects during downstream processing.

The findings of this study are consistent with [49], which highlighted that regular maintenance effectively reduces neps count and sliver unevenness. Unlike [49], which focused on optimizing machine parameters, this study demonstrates that straightforward mechanical cleaning can achieve similar improvements in neps count and U% without complex modifications. Routine maintenance remains essential for SME-scale facilities to attain industry-standard sliver quality.

Both [2] and [6] stated that improper maintenance led to many quality problems in the sliver to yarn production process. Our results showed that repeated cleaning can reduce such problems, thereby validating the role of low-cost interventions in defect prevention.

According to [7], optimization of machine parameters improves sliver consistency and minimizes fiber damage. Their study looked at the tuning of machine settings. Our work showed that mechanical cleaning alone achieved similarly good results without machine parameter adjustments, as it clears blockages from fibers. Thus, mechanical cleaning provides a cost-effective alternative for optimization in practices where constant alterations may be costly for manufacturers.

Because advanced predictive maintenance schemes allow a fault to be detected with precision, they also require significant investments in infrastructure and skilled personnel, making them impractical for many small and medium enterprises (SMEs) [8]. Mechanical cleaning is instead a low-cost, scalable intervention that effectively eliminates fiber tangles without sensor-based monitoring systems [12].

Overall, our findings show that mechanical cleaning alone significantly contributes to the reduction of neps and U%. This intervention offers a practical and economical option for small-scale textile manufacturers aiming to enhance sliver quality without significant financial investment. Previous studies [13] have demonstrated the practical effectiveness of manual and mechanical cleaning methods in removing fiber obstructions, improving the alignment of fibers, and reducing inherent defects. Cleaning has been reported to reduce downtime and energy costs, especially when compared manually to automated cleaning systems, thus becoming an economically viable alternative to sustainable textile manufacturing [11].

The results support [10] and [8], who promoted predictive and modular maintenance strategies for reliability and efficiency improvement, although one study focused on automation and real-time defect monitoring and another on an approach where only regular low-tech cleaning routines can provide a similar improvement in sliver to yarn quality. The implication is for manual interventions to be considered as an alternative to expensive predictive models, at least in SME settings that have no financial and technical resources for sensor-based systems.

[9] indicated that good maintenance would have a major effect on reducing production defects and saving costs. Although they indicated preventive maintenance with advanced scheduling software, our finding indicates that frequent low-cost cleaning could provide the same gains without complex scheduling tools. Thus, simple yet effective maintenance strategies are feasible for textile manufacturers with less technological infrastructure.

This research also addresses a gap not covered by [50] and [51]; both of these studies inquired into need-based evaluations of cleaning methods on sliver quality. Whereas the former focused on surface-level debris removal, the latter developed quantitative evidence regarding deep mechanical cleaning and its impact on neps count and U%. By incorporating statistical analyses, this study moves beyond observation and proposes a data-driven framework on the basis of information for assessing the effectiveness of maintenance interventions.

Also, [25] and [35] emphasized that maintenance is essential for sustainable production by reducing waste and increasing efficiency. While [25] discussed predictive maintenance using sensor networks, this study demonstrates that manual or mechanical cleaning alone can significantly reduce major sliver defects, with potential downstream benefits for yarn quality. Thus, mechanical cleaning serves as a practical alternative for manufacturers with limited resources, offering a cost-effective option compared to expensive predictive systems.

5. CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

The cleaning intervention in this study significantly improved sliver quality, with potential downstream benefits for yarn quality. There were clear reductions in both neps count and U%, along with better production consistency. These findings confirm the importance of regular maintenance for maintaining quality standards in textile manufacturing, especially for factories with limited access to advanced technology.

Mechanical cleaning offers a practical and cost-effective solution. Future research should investigate how to optimize maintenance strategies, combining predictive systems and mechanical cleaning, and examine the effects of cleaning frequency. Studies should also assess long-term impacts, environmental influences, and the cost-effectiveness of different maintenance approaches. Comparative analysis across various carding machines and production lines can help establish specific maintenance recommendations. Addressing these topics will support the development of efficient and effective maintenance protocols in textile production.

REFERENCES

1. S. He, L. Cheng, W. Xue, Y. Cui, Y. Ji, and R. Shao, "Card clothing with spatially morphological teeth and their application verification on carding machine," The Journal of The Textile Institute, vol. 115, no. 6, pp. 948–957, 2024, doi: 10.1080/00405000.2023.2203034.
2. Z. Bin Sayed, N. Afrose, and S. Kabir, "Impact of the Speed of Flat of a Typical Carding Machine on the Quality of Carded Sliver and 40 Ne Yarn," Journal of Textile Science and Technology, vol. 07, no. 01, pp. 66–76, 2021, doi: 10.4236/JTST.2021.71006.
3. Sanjar. Tojimirzaev, H. Parpiyev, and D. H. Parpiyev, "The influence of top flat speed of carding machine on the sliver and yarn quality," Izvestiya vysshikh uchebnykh zavedenii Tekhnologiya legkoi promyshlennosti, vol. 49, no. 3, pp. 85–90, 2020, doi: 10.46418/0021-3489_2020_49_3_15.
4. S. Das and A. Ghosh, "Rough Set-Based Decision Tool for Classification of Cotton Yarn Neps," Journal of The Institution of Engineers (India): Series E, vol. 102, no. 1, pp. 1–10, Jun. 2021, doi: 10.1007/S40034-020-00173-2/METRICS.
5. Y. Liu, G. Zhu, J. Zhong, G. Han, M. Xing, and N. Sun, "Study of sliver irregularity caused by fiber acceleration motion during the drafting process," Textile Research Journal, vol. 94, no. 5–6, pp. 704–712, Mar. 2024, doi: 10.1177/00405175231212230.
6. W. A. Subakdo, "The effect of top roll defects on dyh5000 toyoda hara finisher draw frame on sliver unevenness at pt xyz," IOP Conf Ser Mater Sci Eng, vol. 885, no. 1, p. 012042, Jul. 2020, doi: 10.1088/1757-899X/885/1/012042.
7. Q. Guo, J. Hang, S. Wang, W. Hui, and Z. Xie, "Buckling optimization of variable stiffness composite cylinders by using multi-fidelity surrogate models," Thin-Walled Structures, vol. 156, Nov. 2020, doi: 10.1016/J.TWS.2020.107014.
8. Q. Chen, J. Xu, and S. Zhang, "Cylindricity and flatness optimization for mechanical parts in additive manufacturing based on tolerance adaptive slicing," The International Journal of Advanced Manufacturing Technology, vol. 115, no. 11–12, pp. 3839–3857, Aug. 2021, doi: 10.1007/S00170-021-07271-4.
9. V. V. Shanbhag, T. J. J. Meyer, L. W. Caspers, and R. Schlanbusch, "Failure Monitoring and Predictive Maintenance of Hydraulic Cylinder—State-of-the-Art Review," IEEE/ASME Transactions on Mechatronics, vol. 26, no. 6, pp. 3087–3103, Dec. 2021, doi: 10.1109/TMECH.2021.3053173.
10. M. Yuan, S. Zhang, P. Yang, and Y. Deng, "Deep Learning-Based Predictive Maintenance Model for Air Cylinder in Manufacturing Systems," 2023 5th International Conference on Robotics, Intelligent Control and Artificial Intelligence (RICAI), pp. 625–629, 2023, doi: 10.1109/RICAI60863.2023.10489303.
11. V. Mahalakshmi and S. Sowmiya, "Care And Maintenance Of Textile," Care And Maintenance Of Textile, Apr. 2023, doi: 10.26524/ROYAL.193.
12. A. Djuraev, R. Rosulov, J. Kholmirzaev, H. Diyorov, and U. Berdimurodov, "Development of effective construction and justification of parameters of the cleaner of fibrous material," E3S Web of Conferences, vol. 304, p. 03031, Sep. 2021, doi: 10.1051/e3sconf/202130403031.
13. F. Egamberdiev, K. Jumaniyazov, I. Abbazov, and H. Yodgorova, "Theoretical study of the effect of improving cleaning efficiency and fiber quality from a double-drum fiber cleaner," IOP Conf Ser Earth Environ Sci, vol. 1142, no. 1, p. 012088, Mar. 2023, doi: 10.1088/1755-1315/1142/1/012088.
14. O. Paraska et al., "Usage Of Biosurfactants As Environmental Friendly Detergents For Textile Products Cleaning," Fibres and

Textiles, vol. 30, no. 5, pp. 42–51, 2023, doi: 10.15240/tul/008/2023-5-005.

15. K. Laitala, I. G. Klepp, and V. Haugrønning, "Textile Cleaning and Odour Removal," Odour in Textiles, pp. 197–223, Mar. 2022, doi: 10.1201/9781003141426-10.
16. E. Bonnail, S. Vera, J. Blasco, and T. Á. DelValls, "Towards a Cleaner Textile Industry: Using ASEC to Decrease the Water Footprint to Zero Liquid Discharge," Water 2023, Vol. 15, Page 3781, vol. 15, no. 21, p. 3781, Oct. 2023, doi: 10.3390/W15213781.
17. M. M. Rashid, K. A. Motaleb, and A. N. Khan, "Effect of flat speed of carding machine on the carded sliver and yarn quality," J Eng Fiber Fabr, vol. 14, Apr. 2019, doi: 10.1177/1558925019845183/ASSET/IMAGES/LARGE/10.1177_1558925019845183-FIG9.JPEG.
18. R. K. Singh and A. Gurtu, "Prioritizing success factors for implementing total productive maintenance (TPM)," J Qual Maint Eng, vol. 28, no. 4, pp. 810–830, Oct. 2022, doi: 10.1108/JQME-09-2020-0098/FULL/PDF.
19. S. H. Sasono, A. S. Nugroho, E. Supriyanto, A. Hasan, and E. Wasito, "IoT Smart Health for Monitoring and Control of Temperature and Humidity of Vaccine and Drug Storage based on Android at Health Center," JAICT, vol. 7, no. 2, pp. 119–124, Oct. 2022, doi: 10.32497/JAICT.V7I2.3911.
20. D. Harianto, H. S. Bintang, A. Ardiyanto, and V. L. D. Widyawan, "Development and Evaluation of an ESP32-based Temperature and Humidity Control Unit for Textile Storage," International Journal of Engineering Continuity, vol. 4, no. 1, pp. 1–19, Nov. 2024, doi: 10.58291/IJEC.V4I1.309.
21. M. F. Khurshid, A. Abdkader, and C. Cherif, "Processing of waste carbon and polyamide fibres for high-performance thermoplastic composites: influence of carding parameters on fibre orientation, fibre length and sliver cohesion force," The Journal of The Textile Institute, vol. 111, no. 9, pp. 1277–1287, Sep. 2020, doi: 10.1080/00405000.2019.1690918.
22. W. Gu, F. Li, Y. Cao, Q. Gao, and C. Zhuo, "Carding Behavior and Bearing Capacity of a Newly Developed Cylinder Card-Clothing Compatible with Cotton and Terylene Fibers by Nb Alloying of AISI 1090 Steel," Materials, vol. 17, no. 7, Apr. 2024, doi: 10.3390/MA17071511.
23. P. P. Kolte, "Optimization of carding machine speed parameters," Melliand International, vol. 26, no. 4, pp. 171–172, 2020, [Online]. Available: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85099571776&origin=inward
24. N. Ahmad, J. Hossen, and S. M. Ali, "Improvement of overall equipment efficiency of ring frame through total productive maintenance: a textile case," International Journal of Advanced Manufacturing Technology, vol. 94, no. 1–4, pp. 239–256, Jan. 2018, doi: 10.1007/s00170-017-0783-2.
25. M. Teklehaimanot, K. Fisseha, and M. Ayele, "Combined Effect of Carding Machine Process Parameters on Yarn Properties; Process Optimization," Tekstilec, vol. 65, no. 1, pp. 58–66, Feb. 2022, doi: 10.14502/TEKSTILEC.65.2021020.
26. M. Amejwal, A. El Jaouhari, J. Arif, S. Fellaki, and F. Jawab, "Production Flow Management Based on Industry 4.0 Technologies," 2022 IEEE 14th International Conference of Logistics and Supply Chain Management, LOGISTIQUA 2022, 2022, doi: 10.1109/LOGISTIQUA55056.2022.9938064.
27. J. E. Velázquez-Mancilla, M. C. Fierro-Xochitototl, and J. Chávez-Medina, "Estandarización del proceso de confección, a través de la ingeniería de métodos, para aumentar la productividad, en una empresa del ramo textil en el estado de Puebla," Revista de Ingeniería Industrial, pp. 1–7, Jun. 2020, doi: 10.35429/JIE.2020.13.4.1.7.
28. B. Li, "Parameter optimization design and experiment of famous tea continuous carding machine," Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, vol. 40, no. 10, pp. 276–287, 2024, doi: 10.11975/j.issn.1002-6819.202312195.
29. G. Murzabayeva, "The influence of the average residence time of the fiber in the set of the main drum and the flats of the carding machine on the carding degree," 2024. doi: 10.1051/e3sconf/202447401025.
30. S. Ramamoorthy, "Evaluation of yarn and fabric properties of environmentally friendly and sustainable chiengora fibers from Pomeranian dog breed for textile applications," Journal of Natural Fibers, vol. 19, no. 14, pp. 8946–8959, 2022, doi: 10.1080/15440478.2021.1975601.
31. M. Pech, J. Vrchota, and J. Bednář, "Predictive Maintenance and Intelligent Sensors in Smart Factory: Review," Sensors 2021, Vol. 21, Page 1470, vol. 21, no. 4, p. 1470, Feb. 2021, doi: 10.3390/S21041470.
32. T. Takahashi, M. Hayashi, Y. Watanabe, H. Sadatomi, K. Matsumoto, and E. Shono, "Improving the adsorption performance and surface roughening of rayon fibers via enzymatic treatment with cellulase," Textile Research Journal, vol. 91, no. 5–6, pp. 589–598, Mar. 2021, doi: 10.1177/0040517520932394.
33. H. S. Bintang et al., "Perbaikan Kualitas Neps Sliver Rayon Pada Proses Carding Dengan Metode Dmaic," PROSIDING SNAST, pp. C8-14, Nov. 2024, doi: 10.34151/PROSIDINGSNAST.V1I1.4991.
34. A. T. Alamirew and G. B. Tesema, "Optimizing Carding Speed Parameters and C-60 RSB Draft to Improve Sliver Quality," Journal of Natural Fibers, vol. 21, no. 1, Dec. 2024, doi: 10.1080/15440478.2024.2337044.
35. Md. M. Motin, A. N. Khan, and Md. O. Rahman, "Study on Licker-In and Flat Speeds of Carding Machine and Its Effects on Quality of Cotton Spinning Process," Journal of Textile Science and Technology, vol. 9, no. 3, pp. 198–214, Jul. 2023, doi: 10.4236/JTST.2023.93013.
36. A. Bogdanowicz, M. Zacharewicz, and J. Król, "The Use of a Microcontrollers in Hygrometric Measurements Application," Scientific Journal of Polish Naval Academy, vol. 220–221, no. 1–2, pp. 47–57, Jun. 2020, doi: 10.2478/sjpna-2020-0004.
37. Badan Standardisasi Nasional, "SNI 08-0261-1989 Kondisi ruangan untuk pengujian serat, benang, dan kain kapas.," 1989.
38. Badan Standardisasi Nasional, "SNI 08-0262-1989 Kondisi contoh uji untuk pengujian serat benang dan kain kapas," 1989.
39. E. A. Korol, E. N. Degaev, and S. L. Pushenko, "Determination of the Convergence of Intra-Laboratory Measurements of Dust Content on a Construction Site," Safety of Technogenic and Natural Systems, no. 1, pp. 30–40, Feb. 2024, doi: 10.23947/2541-9129-2024-8-1-30-40.
40. PT Danliris Tbk., "Standar Neps dan U%," Sukoharjo, 2025.
41. D. Harianto, S. Sugiyarto, and R. N. Azizah, "Perbandingan Kinerja Yarn Guide tipe Pig tail dan Snail Wire dalam Kualitas Hairiness Benang Ring Spinning Frame," Jurnal Tekstil: Jurnal Keilmuan dan Aplikasi Bidang Tekstil dan Manajemen Industri, vol. 7, no. 2, pp. 111–119, Dec. 2024, doi: 10.59432/jute.v7i2.108.
42. Yongxin. Chen, Kamal. Djidjeli, and Z. Tong. Xie, "Large eddy simulation of flow past stationary and oscillating square cylinders," J Fluids Struct, vol. 97, Aug. 2020, doi: 10.1016/J.JFLUIDSTRUCTS.2020.103107.
43. B. Ma, R. Gao, J. Zhang, and X. Zhu, "A YOLOX-Based Automatic Monitoring Approach of Broken Wires in Prestressed Concrete

Cylinder Pipe Using Fiber-Optic Distributed Acoustic Sensors," Sensors (Basel), vol. 23, no. 4, Feb. 2023, doi: 10.3390/S23042090.

44. E. Manik, A. Affandi, S. Priadana, D. Hadian, and D. A. Puspitaningrum, "Comparison of Normality Testing with Chi Quadrat Calculations and Tables for The Statistical Value Departement of Elementary School Education Student at the University of Jember," AIP Conf Proc, vol. 2679, no. 1, Jan. 2023, doi: 10.1063/5.0111307/2868526.
45. A. P. . Field, "Discovering statistics using IBM SPSS statistics," p. 1110, 2024.
46. F. Habibzadeh, "Data Distribution: Normal or Abnormal?," J Korean Med Sci, vol. 39, no. 3, 2024, doi: 10.3346/JKMS.2024.39.E35.
47. M. Shuttleworth, "Student's t Test," The SAGE Encyclopedia of Research Design, 2022, doi: 10.4135/9781071812082.N613.
48. T. W. MacFarland, "Student's t-Test for Independent Samples," Using R for Biostatistics, pp. 17–46, 2020, doi: 10.1007/978-3-319-02532-2_3.
49. S. He, L. Cheng, W. Xue, Z. Lu, L. Chen, and R. Shao, "Card clothing with misaligned teeth for the card: Carding mechanism and application," Textile Research Journal, vol. 93, no. 1–2, pp. 124–132, Jan. 2023, doi: 10.1177/00405175221116595/ASSET/IMAGES/LARGE/10.1177_00405175221116595-FIG6.JPEG.
50. N. Barrientos-Ramos, L. Tapia-Cayetano, F. Maradiegue-Tuesta, and C. A. Raymundo-Ibañez, "Lean Manufacturing Model of Waste Reduction Using Standardized Work to Reduce the Defect Rate in Textile MSEs," Aug. 15, 2020.
51. N. Ingle and W. J. Jasper, "A review of deep learning within the framework of artificial intelligence for enhanced fiber and yarn quality," Textile research journal, 2024, doi: 10.1177/00405175241265510.