*Modern American Journal of Engineering, Technology, and Innovation*
**ISSN(E):** 3067-7939
Volume 01, Issue 03, June, 2025
**Website:** usajournals.org

# EVALUATION OF THE INFLUENCE OF SLIVER STRUCTURAL COMPOSITION AND CLEANLINESS ON YARN QUALITY

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**Abstract**:
This article presents a scientific analysis of how the structural quality and cleanliness of the feeding sliver affect the physical and mechanical properties of yarn in the ring spinning process. Based on experimental data and scientific studies, the relationship between fiber parallelization, density uniformity, neps content, and external impurities in the sliver and the resulting yarn quality is examined. The findings indicate that a high degree of fiber parallelization and cleanliness significantly improves yarn strength, evenness (U%), and surface smoothness. It is also shown that a two-stage sliver preparation process and modern monitoring systems reduce yarn breakage rates. In conclusion, the use of

structurally stable and clean slivers is identified as a key factor in producing high-quality yarn in ring spinning systems.

**Keywords:** Ring spinning, sliver quality, fiber parallelization, yarn unevenness, twist distribution, sliver cleanliness, neps content, yarn strength, smoothness, technological stages, spinning process stability.

## Introduction

One of the key prerequisites for producing high-quality yarn is the continuous and uniform delivery of well-opened, carded, and parallelized fibers to the ring spinning zone, i.e., to the spinning triangle through the drafting rollers. In the ring spinning process in particular, the evenness and structural uniformity of the sliver entering the drafting zone have a direct impact on the yarn's strength, unevenness, and surface smoothness. If the fibers in the sliver are improperly aligned or insufficiently cleaned, this can lead to fluctuations in drafting tension, uneven twist distribution along the yarn length, and the formation of surface defects. Furthermore, the consistent and parallel feeding of fibers in ring spinning positively affects the dynamic behavior of the yarn — such as its tensile strength and elasticity characteristics [1].

## Analysis and Results

S. Klein emphasizes that improved fiber parallelization in ring spinning can reduce yarn unevenness by 15–20%, directly contributing to enhanced yarn quality indicators [2]. According to research by U. Patil, the structural stability of the sliver entering the drafting zone shows a strong correlation with twist distribution and yarn tensile strength [3]. G. Grosberg discovered that any pulsation in fiber feeding during the ring spinning process increases surface roughness in the yarn, and demonstrated that this effect originates from micro-irregularities present in the sliver [4]. T. Behera, through experimental analysis, showed that the cleanliness level of the sliver can increase the risk of moiré effect formation in ring-spun yarns by up to 30% [5].

The irregularities in the supplied sliver have a significant impact on the structural smoothness and unevenness of yarn produced by ring spinning. Variations in the density of the sliver entering the drafting zone cause disruptions in twist distribution, leading to indistinct segments, surface roughness, and localized weak zones in the yarn. Particularly in ring spinning, where the draft ratio ranges between 80 and 100 times, even micro-irregularities as small as 1 cm in the sliver directly affect more than 1 meter of yarn length. Yarn quality indicators (U%, CVm%, imperfections) exhibit a linear correlation with the weight irregularities of the sliver, which is especially noticeable in coarse and fine yarns [6].

Research has shown that even a slight increase of 0.3% in the CVm% value of the sliver results in an 18% rise in the total number of defects observed in the yarn. This highlights the critical importance of sliver uniformity in producing high-quality yarn through ring spinning. From this perspective, the degree of fiber alignment in the sliver is also of great significance. During the combing stage, this coefficient ranges from 0.65 to 0.7, increases to 0.7–0.75 after the first passage through the carding machine, and further rises to 0.75–0.8 after the second passage. Throughout these stages, fiber parallelization improves, enabling the delivery of higher-quality material to the spinning zone (see Figure 1). The following graphs illustrate how yarn quality parameters improve with each technological stage: breaking force (Ro) and elongation (Er) steadily increase, while unevenness (U%) decreases. Notably, for 26 tex yarn (b), these changes show a linear and stable trend. This indicates that the sliver is one of the primary factors determining yarn quality indicators in ring spinning.

A high degree of fiber parallelization further enhances this positive effect. In the ring spinning process, the parallelism of fibers in the sliver plays a crucial role in the yarn’s resistance to deformation, uniformity of twist, and strength. If fibers in the sliver are oriented irregularly or entangled, they stretch under varying tensions in the drafting zone, causing localized structural changes in the yarn. This leads to increased unevenness (U%) and weak zones in the yarn. Conversely, highly parallelized fibers stretch uniformly under consistent tension in the drafting zone, resulting in yarn with stable twist distribution. Research by J.K. Kilic [7] demonstrated that delivering fibers to the ring spinning zone with maximal parallelization reduced the yarn’s Uster unevenness value from 14% to 11.2%. This indicates that optimizing the internal structure of the sliver significantly improves the quality of the produced yarn.

The above information demonstrates that the structural quality of the sliver and the parallelism of fibers directly affect the primary physical and mechanical properties of the yarn. This relationship is clearly observed in Figure 1: as the number of technological stages increases, fiber parallelism in the sliver improves, resulting in a steady increase in the yarn's specific breaking force (Ro, sN/tex) and elongation (Er, %). At the same time, the yarn's unevenness (U%) sharply decreases, significantly enhancing the yarn's appearance and processing performance.

A high degree of fiber parallelization affects not only quality indicators but also the stability of the yarn and the frequency of breaks during processing. Experiments conducted by A.A. Chishoim [8] revealed that yarns spun from slivers prepared through a two-stage carding process significantly outperform those produced from single-stage slivers. Specifically, in the production of 52 tex yarn, the number of breaks per unit length in yarn from the one-stage sliver was 0.83, whereas this value decreased to 0.16 for yarn from the two-stage sliver. This demonstrates that increasing fiber parallelism in the sliver and employing multi-stage processing are highly effective technological solutions to reduce yarn breakage in ring spinning.

Furthermore, in the ring spinning process, the oriented delivery of fibers helps achieve uniform stress distribution within the drafting zone. This, in turn, ensures the formation of yarn with evenly distributed twist, smooth surface, and enhanced strength. The results above scientifically validate that enhancing the internal structure of the sliver allows for the production of high-quality yarn in the ring spinning system.

The structural quality of the supplied sliver, particularly the separation of fibers and cleanliness from impurities, directly affects the mechanical stability of the yarn produced by ring spinning. In the ring spinning process, fibers are continuously fed into the drafting zone, which requires the fibers to be delivered individually and in an orderly manner. If the fibers in the sliver are not fully separated, are entangled, or contaminated with dirt particles, they stretch unevenly between the drafting rollers, resulting in localized weak spots, breaks, and surface roughness in the yarn.

Such fibers interfere with the twisting process in the spinning zone because the yarn cross-section expands unevenly, resulting in an inconsistent twist distribution. Therefore, it is essential to increase the degree of fiber separation and minimize large contaminant particles during the carding stage of slivers intended for ring spinning. Experiments have shown that the Uster unevenness index of yarns spun from cleaner slivers ranges around 12–15%, while for slivers with higher contamination, this value exceeds 18%, and the number of breaks can increase up to 40–60 times per kilogram of yarn.

For example, experiments conducted by M. Saha [9] and colleagues reported that yarns spun from slivers with a 30% reduction in neps and dust particles experienced 1.9 times fewer breaks compared to yarns spun from unregulated slivers. These results confirm the critical importance of clean, structurally well-separated slivers for the stability of the ring spinning process and yarn quality.

The internal structural quality of the sliver directly affects all layers of the yarn formed during ring spinning. Throughout the process, fibers delivered from the drafting zone continuously enter the twist-formation zone, where the central yarn core is formed. This core primarily consists of fibers that are precisely aligned and uniformly tensioned. Additionally, apart from variations in drafting force, irregularities in the sliver cause fibers to be randomly distributed on the yarn surface, forming the cover layer. These surface fibers mainly influence the external structure of the yarn, affecting its smoothness, strength, and cohesion properties during processing with neighboring yarns.

If the fibers in the sliver are not fully separated or are in a mixed state, they may not be properly drafted into the twist zone, leading to the formation of weak, loosely structured zones within the yarn. This reduces the structural integrity of the yarn, making it soft and weak. Such yarns typically fail to meet technical standards and are classified as “second grade.”

Contaminants in the supplying sliver—particularly plant residues, dust, and oily substances—pass through the drafting rollers and adversely affect yarn formation. These particles create micro-unevenness in the yarn cross-section and disrupt the proper distribution of twist tension. As noted by F. Stahleker [10], this results in an increased Uster unevenness index and decreased strength of the yarn. H. Stalder [11] also highlights that the moiré effect—linear color variations on the yarn surface caused by contaminants—is a visual indicator of quality deterioration.

Furthermore, fibers entering the twist zone at incorrect angles contribute to structural unevenness in the yarn. Especially when fibers in the sliver are positioned at an angle to the drafting direction, the risk of knot formation increases. This negatively impacts the yarn's smoothness and mechanical stability.

The stable formation of yarn depends not only on the cleanliness and separation of fibers but also on their orientation as they enter the twist zone. In ring spinning, after the drafting zone, the yarn formation stage begins, during which the fibers start to move in a spiral manner. If the fibers enter this zone asymmetrically or at varying lengths, the twist distribution becomes inconsistent. As a result, fluctuations in yarn diameter, thick places, thin places, and even imperfections appear on the yarn surface [12].

The vibrations of the rapidly rotating ring and ring traveler in the spinning zone directly affect the yarn's cover layer. Fibers located in this layer, especially if they are disordered or misaligned, reduce the yarn's smoothness and surface strength. Such yarns may undergo deformation during dyeing, weaving, and subsequent processing, leading to uneven dye absorption or breaks.

Studies have shown that yarns containing contaminants or improperly oriented fibers in the cover layer exhibit non-compliant results in 23–27% of tests. Notably, yarns with a pronounced moiré effect were found to have significantly deteriorated visual quality [13].

The number of defects occurring in the yarn during the spinning process, especially when measured per unit length, is closely related to various technological and raw material factors. By expressing this relationship through a mathematical model, it is possible to predict yarn quality. The following empirical formula, proposed by K.P. Chellamani [14] and colleagues, is used to estimate the number of defects (M) per 1 km of yarn in the ring spinning process:

$$M = Q \cdot Ne^2$$

$$Q = 15{,}129 - 1{,}682 \cdot F - 0{,}646 \cdot L + 3{,}611 \cdot t + 7{,}582 \cdot N$$

Here:
*Ne* – yarn count according to the English system,
*F* – fiber micronaire (fineness),
*L* – upper average fiber length (%),
*t* – ontamination level of the sliver (%),
*N* – number of neps in the sliver (per 100 meters).

Based on this equation, the assessment shows that the uniformity of sliver properties directly affects the number of defects in the yarn. In particular, the coefficients representing contamination level (t) and the number of neps (N) have positive values, meaning that their increase significantly raises the total number of defects in the yarn. Conversely, fiber length (L) and fineness (F) enter with negative coefficients, indicating that as their quality improves, the number of defects in the yarn decreases.

When this model is adapted to parameters specific to the sliver in ring spinning, it enables the prediction of the final yarn quality through the quality of the raw material and intermediate product (sliver) during the manufacturing process. Especially, using slivers composed of fibers that are low in defects, smooth, and highly oriented significantly enhances the ability to produce yarn with stable quality and aesthetic appearance [15-16].

In advanced ring spinning systems developed by leading manufacturers, the quality parameters of the sliver are monitored in real time. Modern sensor-based optical control systems accurately detect neps, mass irregularities of fibers, and levels of external contamination in the sliver. This facilitates the implementation of tailored control algorithms for each spinning position. Specifically, by forecasting and mitigating defects in the yarn in advance, production profitability is increased. This approach allows treating sliver quality stability not only as a single critical quality factor but also as a guarantee of product quality based on complex automated systems

## Conclusion

To conclude, the analyses show that the structural quality and cleanliness of the feed sliver in ring spinning have a direct impact on all important yarn characteristics. The degree of fiber parallelism, length uniformity, nep content, and contamination level are linearly related to the yarn's smoothness, strength, and unevenness. Scientific studies and statistical models confirm that the physical properties of the sliver not only define the quality of the produced yarn but also significantly affect the stability of the spinning process and the frequency of yarn breakage.

Based on the evidence presented here, it can be stated that slivers consisting of highly purified, structurally stable, and well-parallelized fibers enable the production of yarn that is high in quality, has low unevenness, smooth surface, and meets aesthetic standards.

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