

ROVING WASTE IN TEXTILE MANUFACTURING: GENERATION, MANAGEMENT, AND SUSTAINABLE SOLUTIONS

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Abstract

Roving waste constitutes a significant yet understudied stream of solid waste within the yarn manufacturing sector, impacting both economic efficiency and environmental sustainability. This study employs a mixed-methods approach to quantify roving waste generation and evaluate the efficacy of various mitigation strategies. A comprehensive waste audit was conducted over a six-month period at three large-scale spinning mills, analyzing waste from different machine types and production stages. The results indicate that roving waste accounts for approximately 3.5-5.2% of total production volume, with primary causes attributed to mechanical inefficiencies (42%), operator handling errors (31%), and raw material variability (27%). Furthermore, the implementation of an integrated waste management protocol, combining machine calibration, operator training, and in-process recycling, demonstrated a 47% reduction in waste generation and a projected annual cost saving of \$18.50 per metric ton of production. The findings underscore the critical importance of proactive waste management strategies in enhancing the circularity and profitability of textile manufacturing operations.

Keywords: Roving waste, textile manufacturing, waste minimization, recycling technologies, circular economy, sustainable production, spinning process, waste audit.

Introduction

The global textile industry, a cornerstone of modern manufacturing, faces intensifying pressure to mitigate its substantial environmental footprint, particularly concerning resource consumption and waste generation [1]. Within the multi-stage yarn production process, the spinning phase is a significant contributor to solid waste, of which roving waste—the imperfect or broken sliver produced during the roving and subsequent spinning stages—represents a considerable portion [2]. Economically, this waste translates into direct financial losses from wasted raw materials, increased energy and water consumption per unit of output, and additional costs associated with waste handling and disposal [3]. Environmentally, the disposal of cellulosic and synthetic roving waste in landfills contributes to methane emissions and represents an inefficient linear use of valuable resources [4].

Despite its prevalence, roving waste has not received the same level of scholarly attention as post-consumer textile waste or effluent management. A critical gap exists in the empirical quantification of its generation rates and the systematic evaluation of evidence-based reduction strategies within industrial settings [5]. Previous studies have often focused on broader categories of textile waste or have been limited to theoretical models without practical validation [6]. Therefore, a rigorous, data-driven analysis is imperative to develop effective mitigation frameworks.

This study aims to address this research gap through three primary objectives: (1) to quantitatively assess the volume and primary causes of roving waste generation in industrial spinning mills; (2) to evaluate the effectiveness of a multi-faceted intervention protocol combining technological, operational, and human-factor solutions; and (3) to propose a scalable model for roving waste valorization within a circular economy framework. The insights derived from this research will provide valuable guidance for industry practitioners seeking to improve sustainability metrics and reduce production costs, while also contributing to the academic discourse on industrial ecology and waste minimization.

2. METHODOLOGY

2.1. Research Design

This study utilized a sequential mixed-methods research design, combining quantitative data collection from waste audits with qualitative insights from semi-structured interviews and process observation. The research was conducted in three phases: (1) Baseline Assessment, (2) Intervention Implementation, and (3) Post-Intervention Evaluation, spanning a total duration of nine months.

2.2. Data Collection Methods

2.2.1. Waste Audit: A detailed waste audit was performed over a six-month period at three participating spinning mills (located in different regions to account for variability). Each facility produced cotton and cotton-polyester blended yarns. Waste was collected, segregated, and weighed daily from key points: the roving frame (speed frame), the ring frame creel, and the piecing operations. The data was normalized per metric ton of production output.

2.2.2. Cause Analysis: The root causes of waste generation were investigated through:

- Technical Analysis: Machine settings, roving tension, spindle speed, and humidity levels were recorded and correlated with waste data.
- Process Observation: Skilled observers documented operator handling practices, breakage rates, and waste collection procedures.
- Interviews: Semi-structured interviews were conducted with 25 production managers, machine operators, and maintenance engineers to identify perceived challenges and solutions.

2.2.3. Intervention Protocol: Based on the baseline findings, an integrated intervention protocol was designed and implemented for a three-month period. The protocol consisted of:

- Mechanical Optimization: Calibration of drafting systems and tension devices on roving and ring frames.

- **Operational Training:** A standardized training program for operators on best practices for handling roving, reducing breakage, and efficient waste collection.

- **Process Change:** Introduction of an in-process recycling system where clean roving waste was automatically fed back into the drawing frame process at a controlled blend ratio (up to 5%).

2.2.4. **Data Analysis:** Quantitative data from waste audits were analyzed using descriptive statistics (means, standard deviations) and inferential statistics (paired t-tests to compare pre- and post-intervention waste levels). Qualitative data from interviews and observations were analyzed using thematic analysis to identify recurring themes and patterns.

3. RESULTS AND DISCUSSION

3.1. **Roving Waste Generation Rates and Causes.** The baseline waste audit revealed that roving waste accounted for an average of 4.3% ($\pm 0.7\%$) of total production volume across the three mills. This aligns with earlier estimates suggesting that 3-8% of raw material is lost as soft waste in spinning [7]. As shown in Figure 1, the waste was generated at different stages:

- **Roving Frame (Speed Frame):** 1.8% (End breaks and sliver breaks)
- **Ring Frame Creel:** 2.1% (Roving breaks during unwinding)
- **Piecing Operations:** 0.4% (Waste from manual piecing)

The root cause analysis, summarized in Figure 2, identified three primary contributors:

1. **Mechanical Inefficiencies (42%):** Misaligned drafting systems, worn-out aprons and cots, and improper tension settings were the dominant factors. This finding is consistent with Kumar & Gupta's [8] emphasis on machine conditioning.

2. **Operator Handling (31%):** Improper handling of roving bobbins, causing surface layer damage, and inefficient piecing techniques significantly increased waste. This underscores the human factor highlighted by Sharma & Dangi [9].

3. **Raw Material Variability (27%):** Inconsistent fiber quality, particularly short fiber content and uneven sliver from the drawing stage, directly increased breakage rates at the roving and ring frames, supporting the conclusions of Turker & Altun [10].

3.2. **Intervention Effectiveness.** The implementation of the integrated waste management protocol yielded significant results. As presented in Table 1, the total roving waste was reduced from an average of 4.3% to 2.3% of production volume, representing a 47% reduction.

Mechanical Optimization contributed the most significant reduction (~60% of the total reduction), validating that machine health is the foremost priority for waste minimization [8]. Operator Training led to a ~25% reduction in preventable waste, demonstrating that technology alone is insufficient without skilled human operation [9].

In-process Recycling successfully valorized approximately 0.8% of the waste stream by reintroducing it into the production cycle, creating a closed-loop system within the mill, a concept advocated by the Ellen MacArthur Foundation [11].

Economically, this reduction translated to a saving of \$18.50 per metric ton of yarn produced, considering the cost of raw material, energy, and waste disposal. This provides a strong

economic incentive for mills to invest in such protocols, as suggested by Jørgensen & Jensen [12].

3.3. Discussion: Towards a Circular Model for Roving Waste. The results demonstrate that a systematic, multi-pronged approach is highly effective in tackling roving waste. The study moves beyond the theoretical frameworks often proposed in the literature [6, 11] by providing empirical evidence from industrial applications.

The success of the in-process recycling initiative is particularly noteworthy. While others have explored recycling into nonwovens [13], our study shows that direct reintroduction into the main yarn production line is feasible at low blend percentages without compromising yarn quality, provided the waste is clean and properly blended. This offers a more direct and valuable valorization pathway.

However, challenges remain. The effectiveness of the intervention was somewhat dependent on the initial mill conditions and management commitment. Furthermore, the recycling potential is limited by the need for high-quality, uncontaminated waste streams. For wastes that cannot be recycled in-house, alternative pathways such as conversion into nonwovens or composite materials [13, 14] must be developed in collaboration with downstream sectors, creating a cross-industry symbiosis as envisioned in circular economy models [11].

This research confirms that roving waste is not an inevitable byproduct but a manageable resource inefficiency. By adopting a holistic view that integrates machine, process, and human elements, spinning mills can achieve substantial economic and environmental benefits.

4. CONCLUSION

This study provides a comprehensive, empirical analysis of roving waste in textile spinning mills, establishing a clear link between specific operational factors and waste generation. The key conclusion is that roving waste, representing a significant loss of 3.5-5.2% of production, is primarily driven by mechanical inefficiencies, operator handling errors, and raw material issues. Crucially, this waste stream is highly reducible through a targeted intervention strategy. The implemented protocol, combining mechanical optimization, operator training, and in-process recycling, proved to be exceptionally effective, achieving a 47% reduction in waste and demonstrating compelling economic savings. This validates the hypothesis that a systemic approach is far more effective than isolated measures.

For industry practitioners, the findings underscore the necessity of regular preventive maintenance, continuous operator training, and the exploration of internal recycling loops. For researchers, this study lays a foundation for future work on advanced monitoring systems (e.g., AI for predictive maintenance) [15] and more sophisticated chemical recycling methods for blended fiber wastes that are difficult to recycle mechanically.

Ultimately, managing roving waste is a critical step in the textile industry's journey towards circularity. By transforming waste from a cost center into a valuable resource, the industry can significantly enhance its sustainability and profitability. Future efforts should focus on standardizing these practices across the industry and fostering innovation in recycling technologies to handle more complex waste streams.

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