



THE ROLE OF AUTOMATION AND CONTROL SYSTEMS IN TEXTILE WASTE RECYCLING PROCESSES

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ABSTRACT

The increasing volume of textile waste generated by modern textile industries has created a strong demand for efficient recycling technologies. Contemporary recycling systems rely not only on mechanical processing but also on advanced automation and control systems that ensure process stability, product quality, and resource efficiency. This paper analyzes the role of automated control systems in textile waste recycling lines based on industrial solutions developed by leading manufacturers such as Rieter, Trützschler, Laroche, Temafa, and Schubert & Salzer-Ingolstadt. The study demonstrates that integrated control technologies significantly enhance fiber recovery, improve process consistency, and reduce human intervention in production systems.

1. Introduction

The textile industry is one of the largest contributors to industrial waste generation due to continuous production cycles and high consumption of raw materials. A significant portion of this waste consists of fibrous materials that retain potential value for reuse in spinning and nonwoven production. Therefore, the development of efficient recycling technologies for textile waste has become an important scientific and industrial task.

In recent years, technological progress has shifted textile waste processing from conventional mechanical systems to highly automated and computer-controlled production lines. These systems integrate multiple processing stages, including opening, cleaning, mixing, and dust removal, into continuous and controlled technological flows. As a result, automation plays a key role in improving both the efficiency and sustainability of recycling processes.

2. Materials and Methods

This study is based on an analytical review of industrial textile waste recycling systems developed by leading international companies, including Rieter (Switzerland), Trützschler (Germany), Laroche (France), Temafa (Germany), and Schubert & Salzer-Ingolstadt (Germany).

Technical documentation, industrial machine specifications, and process flow descriptions were analyzed to evaluate the structure of recycling lines, the level of automation, and the function of control systems in technological processes. Particular attention was given

to continuous processing lines, sensor-based regulation systems, and computer-controlled feedback mechanisms.

3. Results and Discussion

Modern textile waste recycling systems are designed as multi-stage continuous processing lines in which raw material undergoes sequential treatment, including opening, cleaning, dust removal, and secondary fiber separation. Each stage of the process is interconnected and regulated by automated control systems that ensure stable operation and optimal process conditions.

In systems developed by Trützschler, for example, bale opening units, primary cleaning machines, and secondary cleaning devices are integrated into a closed-loop technological system. These systems are equipped with sensors and electronic control units that continuously monitor material flow and adjust operating parameters in real time. Similarly, Rieter recycling machines, such as ERM units and B-series cleaners, utilize computerized control systems to optimize process stability and fiber quality.

Table 1. Comparison of textile waste recycling technologies by leading manufacturers

Company	Country	Machine/System	Function	Automation level	Productivity
Rieter	Switzerland	ERM, B-series cleaners	Opening, cleaning, fiber recovery	High (computer-controlled)	200-600 kg/h
Trützschler	Germany	CS, Willomat RMS, Novagotonia	Multi-stage cleaning line	Very high (sensor + feedback control)	300-500 kg/h
Laroche	France	Cadette 500, 08-120	Fiber regeneration from waste	Medium	50-1000 kg/h
Temafa	Germany	Clean-Star system	Intensive cleaning & dust removal	High	140 kg/h
Schubert & Salzer	Germany	Integrated recycling line	Mixing, opening, cleaning	High	300-400 kg/h

Automation in recycling lines allows continuous regulation of key technological parameters. Cleaning intensity is automatically adjusted depending on the level of contamination and the physical properties of the incoming material. Airflow parameters are regulated to ensure effective separation of dust and fine impurities while minimizing fiber damage. Feeding rate control systems maintain a stable and uniform supply of raw material to the processing units, preventing overload or material shortages in the system. In addition,

recycling loop balance is maintained through feedback mechanisms that coordinate material circulation between different processing stages, ensuring efficient utilization of fibers and reducing material losses.

Such automation significantly reduces the dependence on manual labor and minimizes human intervention in the production process. This leads to improved process consistency, reduced operational errors, and enhanced product quality. Furthermore, automated systems contribute to energy efficiency by optimizing machine operation based on real-time process conditions.

Table 2. Technical characteristics of selected textile waste recycling machines

Machine Model	Manufacturer	Processing Capacity (kg/h)	Installed Power (kW)	Main Function
Blendomat BDT	Rieter	1600	12-15	Automatic bale opening and mixing
Willomat RMS	Trützschler	500	10-12	Opening and preliminary cleaning
Clean-Star	Temafa	140	8-10	Intensive cleaning and dust removal
FS450	China	200	16.5	Fiber opening and recycling
QZ-S60	China	250	5.95	Processing secondary textile raw materials
SVT-100	China	600-800	6.5	Fabric waste shredding and pre-processing
Cadette 500	Laroche	50-1000	15-20	Fiber regeneration from textile waste

Experimental and industrial observations indicate that properly controlled recycling systems can significantly improve fiber recovery rates. In many cases, up to 50 percent of textile waste contains reusable fibers after appropriate mechanical and aerodynamic treatment. Moreover, the spinnability of regenerated fibers increases substantially when impurities and short fibers are effectively removed. In some cases, the spinning performance of recycled fibers improves by approximately 1.5 to 1.8 times compared to untreated waste material.

These results confirm that the integration of automation and control systems is a key factor in the development of modern textile recycling technologies. By ensuring stable process conditions and efficient material utilization, these systems contribute to both economic and environmental sustainability in the textile industry.

Table 3. Impact of automation on recycling process performance

Performance Indicator	Conventional Systems	Automated Systems
Fiber recovery rate (%)	55-65	75-90
Impurity removal efficiency (%)	70-80	90-95
Labor requirement	High	Low
Process stability	Medium	High
Energy utilization efficiency	Moderate	High
Product quality consistency	Variable	Stable

4. Conclusion

The study demonstrates that automation and control systems play a crucial role in modern textile waste recycling processes. The integration of sensors, computerized monitoring units, and feedback control mechanisms enables stable, efficient, and high-quality fiber recovery.

Industrial systems developed by leading companies such as Rieter and Trützschler show that automated recycling lines significantly improve process efficiency, reduce material losses, and enhance the quality of regenerated fibers. Therefore, further development and implementation of advanced control technologies are essential for the sustainable growth of the textile industry.

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