METHODS FOR IMPROVING THE ENERGY EFFICIENCY OF LINTER MACHINES

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Abstract

This article examines the issue of improving the energy efficiency of linter machines used in the cotton industry. The study explores ways to reduce energy consumption, optimize technological processes, and implement automation to ensure rational use of energy resources. The main causes of energy losses in existing machines are analyzed, and technical as well as technological solutions for improving efficiency are proposed.

The paper provides detailed information about the structure, operating principles, and energy performance of linter machines. In addition, modern innovations, automation technologies, and energy-saving systems that enhance operational efficiency are discussed. Practical modernization results demonstrate significant reductions in electricity consumption and improved overall productivity.

Keywords:
Linter machine, energy efficiency, optimization, automation, electric motor, waste heat recovery, energy-saving technologies.

Introduction

Linter machines are an integral part of the cotton processing industry. They are used to separate short fibers remaining on cotton seeds after the ginning process. The linters obtained are valuable secondary raw materials used in textile production, pharmaceuticals, food processing, cellulose manufacturing, and environmentally friendly industrial applications.

The linting process increases product value, improves resource utilization, and reduces waste. In modern production systems, linter machines are designed using advanced technologies that allow automation of processes and optimization of energy consumption.

With increasing global demand for sustainable and energy-efficient production, improving the energy performance of linter machines has become a strategic objective for cotton-processing enterprises. This article discusses the operating principles of linter machines, their application areas, and the main methods for increasing their energy efficiency.

Main Part

Analysis of Existing Problems

Currently, many linter machines in operation have the following shortcomings:

1. High Energy Consumption of Electric Motors

Many enterprises still use IE1 or IE2 class asynchronous motors characterized by:

- Efficiency levels of approximately 75–85%;
- Limited stability under variable load conditions;
- Increased energy losses at elevated temperatures;
- Higher operating and maintenance costs over time.

2. Friction and Mechanical Losses

The working elements of the machine (cylinders, rollers, belts, and cutting blades) operate at high rotational speeds, leading to significant frictional losses. This results in:

- Increased temperature and overheating of materials;
- Higher energy losses;
- Accelerated wear of components;
- Increased maintenance and repair expenses.

3. Insufficient Control Systems

Many machines operate in fixed-speed mode without adapting to variable loads. This leads to:

- Low automation level;
- Continuous operation at high rotational speed even when load decreases;
- Up to 25–30% unnecessary energy consumption during idle or partial-load operation.

4. Inefficient Use of Waste Heat

During operation, considerable heat is generated from motors, bearings, and mechanical components. This heat is typically released into the environment without utilization. However, it could be reused in:

- Heating systems;
- Drying equipment;
- Auxiliary technological processes.

Methods for Improving Energy Efficiency

1. Modernization of the Motor System

1.1 Replacement of conventional asynchronous motors with high-efficiency IE3 or IE4 class electric motors.

1.2 Implementation of Variable Frequency Drives (VFDs) to regulate motor speed automatically according to technological load requirements.

2. Constructive Improvements

2.1 Optimization of the working clearance between rotor and blades to reduce friction losses.

2.2 Adjustment of blade cutting angles to increase fiber separation efficiency while reducing mechanical resistance.

2.3 Use of lightweight and durable materials (e.g., aluminum alloys or composite materials) to reduce inertial mass and mechanical load.

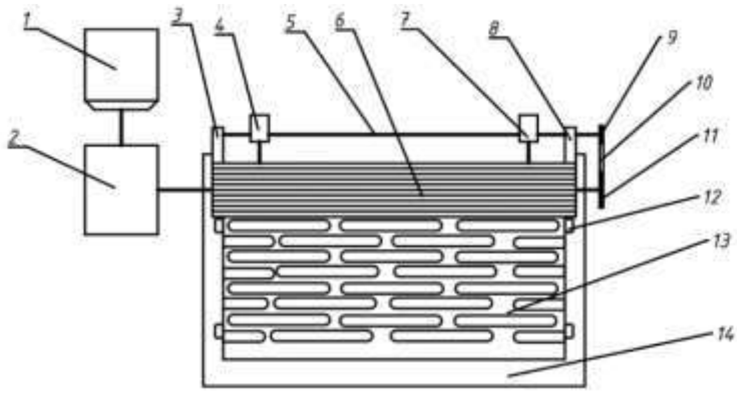
The application of VFD technology enables optimal speed control, reduces peak loads, lowers starting currents, and decreases overall electricity consumption.

In the primary processing technology of cotton, the seeds supplied to the lintering process contain 25–30% small impurities, which negatively affect the quality of the linter (cotton linters). By cleaning these impurities, it becomes possible to maintain the quality in accordance with market requirements.

This task required, within the framework of the dissertation research, the improvement of a linter machine equipped with a cleaning section capable of reducing the impurities contained in the linter. In designing this device, it was taken into account that the objective was to remove impurities from the cotton seeds discharged from the gin machine before they are fed into the linter. For this purpose, a vibratory mesh-surface cleaner was installed in the feeding section of the previously used 5LP model linter machine at industrial enterprises, and it was studied experimentally.

As the goal of the research work, it was necessary to examine the technological capabilities of the newly developed device. The effective operation of the new device, without altering the technological process, depends on the comprehensive perfection of its design. As a result of the research, by sending the cleaned cotton seeds to the lintering process, it becomes possible to reduce the impurities in the linter by 85–90% overall (relative to the initial impurity content in the seeds).

The main working element of the proposed device is a vibrating mesh surface, and the cleaning process largely depends on the efficient operation of this surface. The cleaning surface is shown in Figure 1.



1 – electric motor, 2 – gear reducer, 3 and 8 – brackets, 4 and 7 – eccentric bearings, 5 – shaft, 6 – feeding drum, 9 – driving pulley, 10 – belt, 11 – driven pulley, 12 – bearing, 13 – mesh surface, and 14 – working chamber.

Figure 1. Kinematic diagram of the vibrating mesh surface installed in the feeding section of the 5LP linter machine.

3. Utilization of Thermal Energy

3.1 Introduction of heat recovery (recuperation) systems to reuse thermal energy generated during operation.

3.2 Use of warm air from the aspiration system through heat exchangers in drying processes.

Heat recovery systems not only reduce energy consumption but also contribute to environmental sustainability.

Practical Case Study

In 2024, modernization work was carried out at a cotton processing enterprise in Tashkent region. The results were as follows:

Indicator	Before Modernization	After Modernization
Power per machine	18 kW	13.5 kW
Monthly electricity consumption	21 600 kWh	16 200 kWh
Energy savings	-	~25%

The results demonstrate that upgrading linter equipment can provide substantial annual economic benefits through energy savings alone. In addition, improved automation enhanced operational stability and reduced maintenance downtime.

Conclusion

Linter machines play a crucial role in separating secondary fibers in the cotton industry. Their operational efficiency, particularly in terms of energy consumption, significantly influences the overall economic performance of processing enterprises.

The proposed measures — including modernization of electric motors, implementation of VFD systems, конструктив optimization, and waste heat recovery — allow energy savings of 25–30%. Beyond economic benefits, transitioning to energy-efficient technologies supports environmental sustainability, reduces carbon emissions, and promotes rational resource use.

Improving the energy efficiency of linter machines contributes to reducing the industry's carbon footprint and enhancing competitiveness in global markets. Future research should focus on:

- Integration of smart monitoring systems (IoT-based diagnostics);
- Predictive maintenance using digital twins;
- Implementation of renewable energy sources in cotton processing plants;
- Advanced material engineering for friction reduction.

Adopting green energy principles and innovative production technologies will strengthen the long-term sustainability and global competitiveness of the cotton industry.

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