DYNAMIC ANALYSIS OF SCREW CONVEYORS FOR TRANSPORTING AND CLEANING COTTON LINTER

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Abstract. *The article presents a theoretical analysis of the dynamic characteristics of a screw conveyor designed for the simultaneous transport and mechanical cleaning of cotton linters. A unified dynamic model accounts for the longitudinal displacement of the linter mass resulting from screw rotation, as well as friction, inertia, technological resistance, and time-varying loads. Key parameters identified include screw pitch, diameter, rotational speed, filling coefficient, and the physical-mechanical properties of the material. Based on Newton's second law and the equations of rotational motion, expressions are derived to evaluate drive torque, angular acceleration, and dynamic loading. The presented graphs and tables reflect computational modeling results; parameters for the actual unit require experimental verification. The proposed approach provides a methodological basis for selecting parameters to ensure stable conveyor operation, reduce energy consumption, and minimize mechanical damage to the linters.*

Keywords: *cotton linter, screw conveyor, dynamic analysis, screw pitch, rotational speed, drive torque, friction, productivity, cleaning, mechanical load.*

Introduction. The screw conveyor for transporting and cleaning cotton linters is a mechanical transport and cleaning machine designed to continuously convey linters – generated at cotton cleaning and ginning facilities – over a certain distance while simultaneously separating out fine impurities, dust, seed fragments, leaf particles, motes, and other contaminants through mechanical action and screening. In cotton ginning systems, linters are typically transported via airflow and subsequently passed through condensers and linter cleaners. Therefore, a significant advantage of the screw conveyor is its ability to combine transport and preliminary cleaning functions within a single operating unit.

During the processing of cotton linters, in addition to transporting the material, it is essential to separate fine impurities, ensure uniform flow formation, and maintain stable delivery to the subsequent technological operation. Screw conveyors are well-suited for such processes due to their compact design, continuous operation, and the ability to control the direction of transport. Based on their design and operational characteristics, screw conveyors for linters can be classified into the following groups:

Table 1 [1]

№	Screw conveyor type	Key features	Primary task
1	Simple screw conveyor with an enclosed casing	The screw rotates inside a closed trough	Lint transport
2	Mesh-surface screw conveyor	Perforated/mesh housing or work surface	Transport and separation of fine waste
3	Oscillating-mesh screw conveyor	The mesh surface undergoes oscillatory motion	Transporting, screening, and cleaning
4	Corrugated or profiled screw conveyor	The screw surface has a special profile	Screw surface with a special profile shape
5	Zigzag screw conveyor	The screw threads are formed with a zigzag profile	Transport and intensive mechanical cleaning
6	Wavy-flight screw conveyor	The screw or working surface has a wavy shape	Breaking up and removing the lint layer
7	Kombinatsiyalangan vintli konveyer	Screw + mesh + vibration/aspiration	Transportation and comprehensive cleaning

Figure 1 below shows a screw conveyor in which the screw or working surface is formed with a wavy shape.

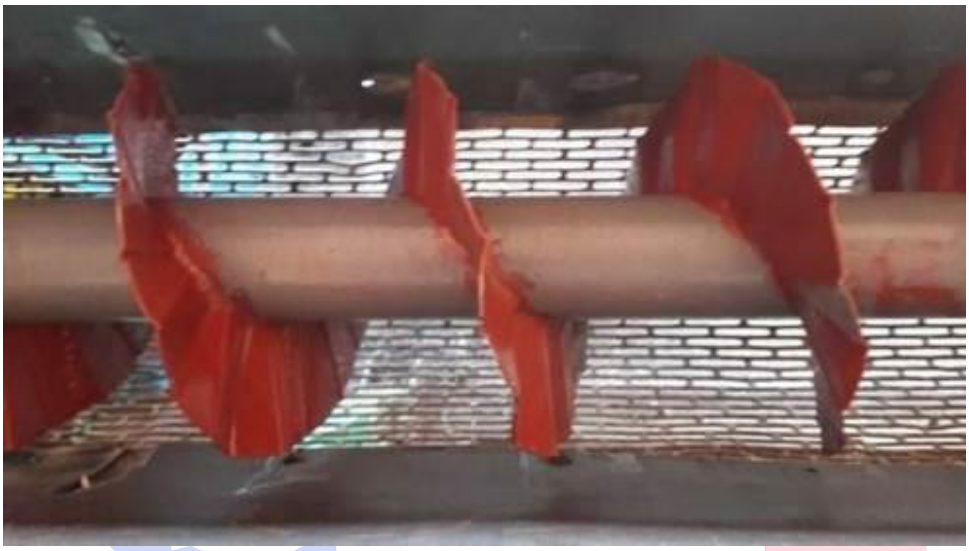


Figure 1. Wave-shaped screw conveyor [2].

The fibrous and lightweight structure of lint complicates its movement compared to granular materials: processes such as snagging, slipping, compression, and re-scattering occur on the screw flight.

For scientific research, the following classification based on screw shape can be used:

Table 2

№	Types of screw working elements based on their structure
1	flat-head (standard) screw
2	ribbon screw
3	paddle-blade screw
4	zigzag-shaped screw
5	wavy screw
6	combined profile screw

From a dynamic perspective, startup, speed fluctuations, irregularities in material flow, and interaction with cleaning elements can cause the drive torque to vary over time. Therefore, it is necessary to evaluate not only static productivity but also the dynamic changes in rotational speed, torque, and acceleration.

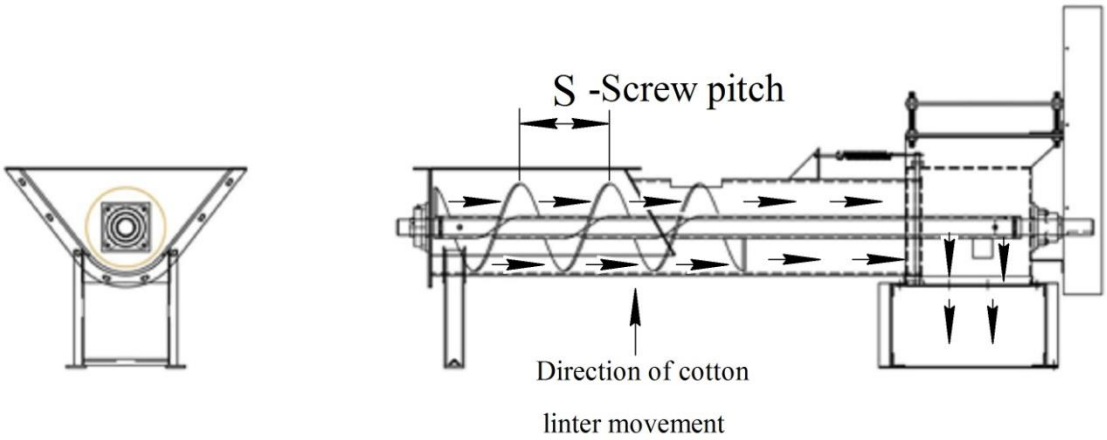


Figure 2. Diagram of a screw conveyor for transporting cotton linters.

The aim of the study is to formulate a simplified dynamic model of a screw conveyor that transports and cleans cotton linters, to determine the primary forces and torques, and to demonstrate the influence of design and kinematic parameters on the operating mode.

The research objectives are presented in Table 3 below:

Table 3

№	Objectives of the research on the dynamic analysis of screw conveyors for transporting and cleaning cotton linters
1	describing the structural scheme
2	separating the forces acting on the link
3	formulating the equations of longitudinal motion and rotational dynamics
4	obtaining model-based calculation graphs
5	developing recommendations for parameter selection

Object of study and theoretical model.

The screw conveyor consists of a casing, a shaft, screw flights, an electric drive, and loading/unloading zones. The dynamic analysis takes into account the screw's moment of inertia (J), angular velocity (ω), drive torque (M_y), resistance torque (M_q), and mechanical losses.

The equation of longitudinal motion for the lint mass element [3] is:

$$m_e \cdot \frac{dv}{dt} = F_t - F_f - F_q - F_d \quad (1)$$

Here, v is the average longitudinal velocity of the screw flow; F_t is the propulsive force of the screw; F_f is the frictional resistance; F_q is the process resistance; and F_d is the additional resistance associated with cleaning and deformation.

Frictional resistance is simply expressed as $F_f = \mu N$.

The rotational dynamics of the screw are [4]:

$J \cdot \frac{d\omega}{dt} = M_y - M_q - M_f$ described by the equation.

The relationship between the rotational frequency n and the angular velocity is $\omega = 2\pi 60$ In an ideal geometric transmission, the material velocity is $v_m = \frac{S \cdot n}{60}$, while in practice, due to slippage and filling, it can be estimated as $v=\varphi \cdot S \cdot n/60, 0<\varphi<1$

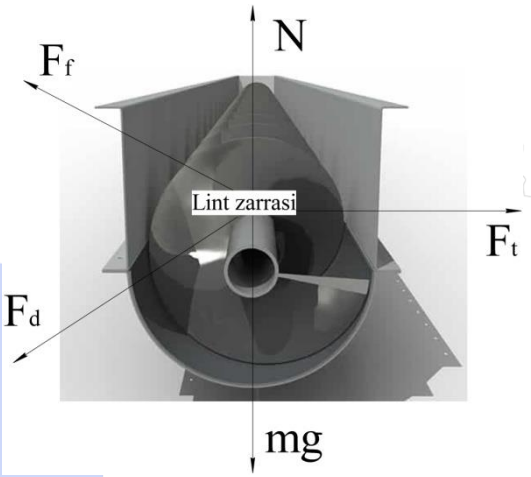


Figure 3. Simplified diagram of the main forces acting on a lint particle.

Mass productivity generally depends on the flow cross-section, longitudinal velocity, bulk density, and filling coefficient.

For a simplified estimate, the expression $Q_m = 60A_e \cdot v \cdot \rho_b \cdot \eta$can be used. Here, Q_m is in kg/min; A_e is the equivalent flow cross-section; ρ_b is the bulk density; and η is the flow utilization coefficient.

Increasing the rotational speed can boost theoretical productivity; however, it also heightens the likelihood of slippage, fiber entanglement, vibration, aerodynamic scattering, and increased resistance torque. Therefore, the optimal operating mode is determined not by the maximum rotational speed, but by the balance between productivity and dynamic loading.

Dynamic calculation results.

The following results are not derived from experiments but represent a sample calculation illustrating the operation of the dynamic model. For an actual unit, the parameters me m_e, J, μ, ρ_b, S, D, L, and the technological resistance coefficients must be determined experimentally. Table 4 below lists the sample parameters adopted for the dynamic model:

Table 4

Model parameters adopted for the dynamic model					
n, rev/min	**S, mm**	**D, mm**	**φ**	**ρ_b, kg/m³**	**Regime**
350	160	250	0,70	45	Low/medium
500	160	250	0,74	45	Close to nominal
650	160	250	0,72	45	High
750	160	250	0,66	45	Slippage may increase

The dynamic influence of the key structural and technological parameters during the transport of cotton linters in a screw conveyor is presented in Table 5 below:

Parametr	**Change**	**Dynamic effect**	**Technical note**
Rotational frequency –n	increase	ω and acceleration increase	Productivity may increase, but the risk of slipping and injury also rises.
Screw pitch –S	increase	The longitudinal feed rate increases	The flow accelerates, and the filling changes
Screw diameter – D	increase	Mass flow and inertia increase	As productivity increases, the drive load also increases
Filling – η	increase	The moment of resistance increases	Overfilling can lead to a blockage
Friction – μ	increase	F_f and M_q increase	Energy consumption and heating may increase
Humidity	change	The sliding and adhesion properties change	Transport and cleaning quality may vary

The mechanical power of the screw conveyor is determined by the formula $P = M_y \cdot \omega$. Taking into account the efficiency η_d the motor power is $P_d = \frac{M_y \cdot \omega}{\eta_d}$. When selecting the drive, factors such as transient starting loads, uneven material feed, resistance to clearing, and a safety margin are taken into consideration.

To reduce dynamic loading, it is advisable to employ soft starting, a frequency converter, shaft balancing, and proper bearing selection, as well as to ensure uniform distribution of the lint flow within the housing.

Discussion. Due to the fibrous structure of cotton linters, their movement within a screw conveyor is more complex than that of classical granular materials. The linters can snag on the screw flight, form layers, or cause localized blockages. Therefore, in future modeling, parameters such as fiber length, moisture content, bulk density, and the coefficient of surface friction must be determined experimentally. During the cleaning process, the time-varying nature of the additional resistive torque can induce torsional vibrations in the drive system. Therefore, it would be scientifically beneficial to experimentally determine $M_{q(t)}$ and employ a two-mass or multi-mass model that accounts for shaft elasticity and the gearbox.

Conclusion. The dynamic behavior of the screw conveyor transporting and cleaning cotton linter can be characterized by simultaneously considering the longitudinal movement of the material and the rotational dynamics of the screw shaft. Rotational frequency, screw pitch, screw diameter, filling coefficient, friction, and technological resistance were identified as the key dynamic factors. The equation of motion for the screw's rotation is expressed as $J \cdot \frac{d\omega}{dt} = M_y - M_q - M_f$ nabling an assessment of how the drive torque varies over time. Increasing the rotational speed can enhance productivity; however, high speeds may also heighten the risks of slippage, vibration, increased energy consumption, and mechanical damage to the fibrous material. For future experiments, it is recommended to simultaneously measure the bulk density, moisture content, friction coefficient, fill factor, drive torque, and vibration amplitude.

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