

The Effect of The Grate Bar Angle of a Pneumo-Mechanical Cleaner on Impact Force Reduction and Lint Self-Discharge

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Abstract

The article presents the results of theoretical studies on selecting the optimal angle of inclination of the grate to the cleaned lint flow, which creates conditions for the unimpeded flow of material along its surface into the working zone of the saw cylinder of the developed pneumomechanical cleaner.

Keywords: lint, air, transportation, grate, impact, equation, velocity, convergence.

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1. Introduction

The operation of in-line lint cleaning systems, where the lint is transported from one processing machine to another by air at a speed of 15-25 m/s, presents a number of challenges.

The first is the complete separation of the air from the transported lint. In existing cleaning machines, this problem is not solved effectively enough, as a portion of the material being cleaned passes through in transit.

The second challenge is preserving the quality of the material being cleaned, as damage to the fibrous materials is observed when the material interacts with the cleaner's working components.

To completely separate the lint flow from the air, a grate has been implemented in the developed pneumomechanical cleaner. A significant increase in the flow cross-section of the inlet pipe allows for a reduction in transport speed, and a reliable grate makes it possible to retain the lint being cleaned. Furthermore, no significant increase in airflow is observed in this zone,

and due to the reduced speed, the correct choice of grate, and the multi-layered lint on the grate's surface, the lint particles deform upon impact with the surface.

According to the developed scheme of the pneumomechanical lint cleaner, moving grate bars are provided for convenient feeding of lint to the saw drum.

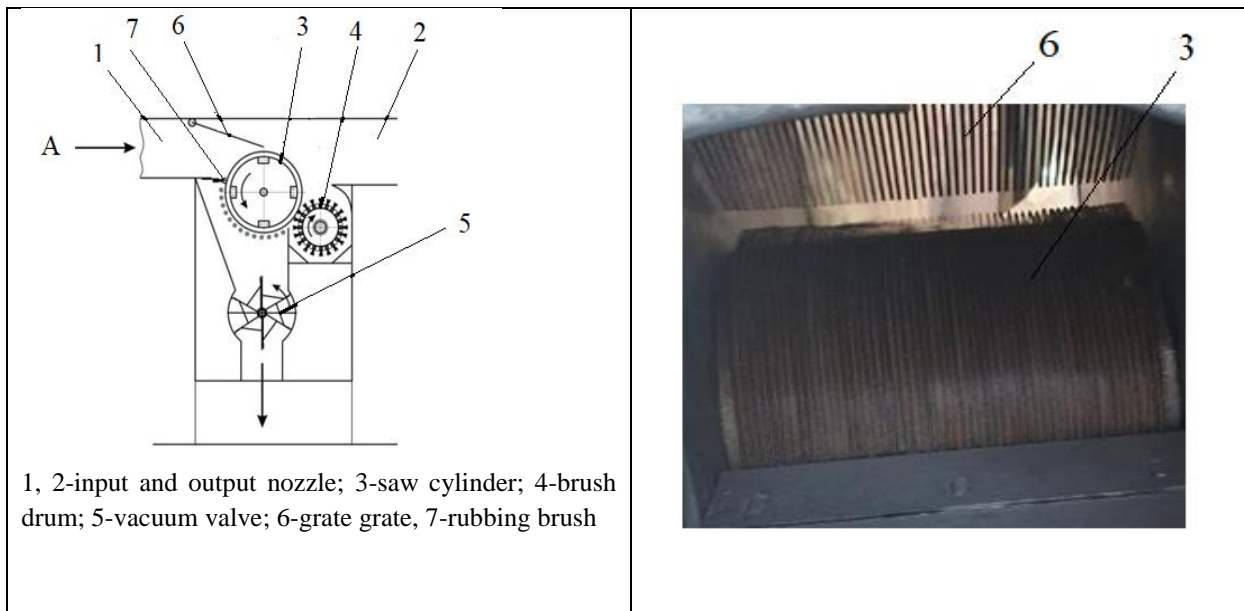


Figure 1. Diagram of the developed pneumomechanical lint cleaner (left) and view according to A for the saw cylinder (3) and grate (6) (right).

Using a guide shield in the form of a grate bar (6), as per our proposed design (Fig. 1), allows for a gradual reduction of the air mixture pressure along the lint's path in the zone where the material particles interact with the teeth of the saw drum (3).

To ensure the elimination of lint bypassing the cleaner from the outlet side, the clear opening of the grate bar is designed to be significantly larger than the cross-section of the cleaner's inlet duct. This prevents backpressure in the airflow and creates the necessary conditions for the lint cleaning process to proceed normally.

One of the crucial factors in ensuring the operational effectiveness of the developed pneumomechanical

cleaner is selecting the optimal angle of inclination for the grate bar relative to the flow of lint being cleaned. This angle creates conditions for the unimpeded descent of the material along its surface into the working zone of the saw cylinder.

Experience shows that during material conveyance, the air velocity cannot be reduced below 16 m/s. Under these conditions, the impact force of the lint particles on the grate bar surface is significant; however, this force can be reduced while maintaining the same airflow velocity characteristics.

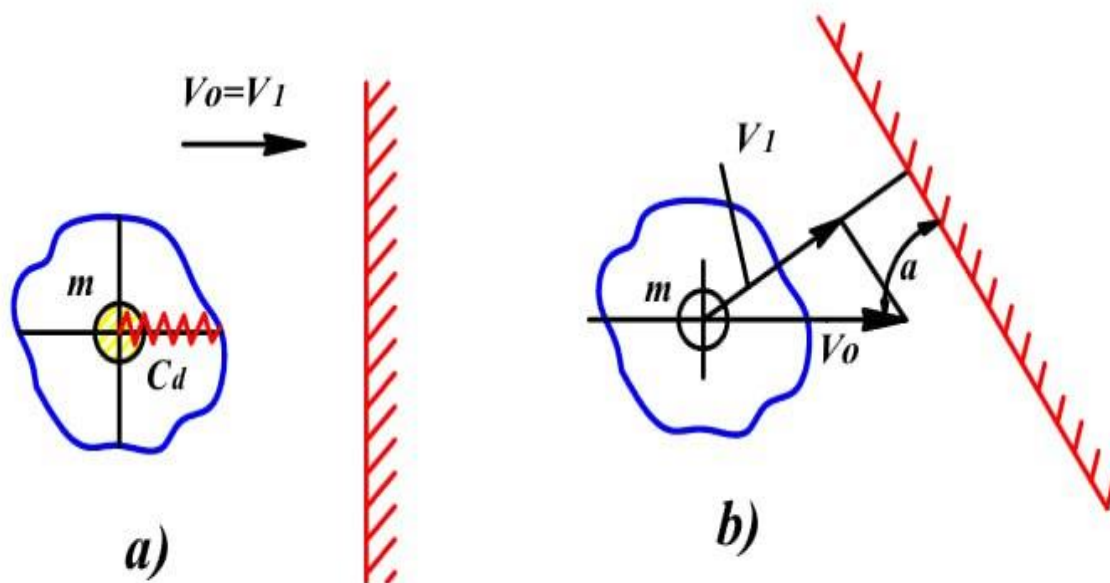


Figure 2. Variants of lint particle impact on the pneumomechanical cleaner grate

Let us consider the impact of lint on a grate bar (Fig. 2a). We will assume the impact to be elastic and the lint mass, m , to be concentrated. The elasticity of the fibrous lint is expressed by the dynamic stiffness coefficient, C_d , and the initial velocity of the lint is denoted as V_0 .

$$m \frac{d^2 x}{dt^2} + C_d x = 0 \tag{1}$$

Let's get maximum deformation

$$x_{\max} = \frac{V_1 \sqrt{m}}{C_d} \tag{2}$$

The impact force will be equal to

$$F_{\max} = V_1 \sqrt{C_d m} \tag{3}$$

This indicates a linear dependence on the working speed V_1 and the stiffness and mass of the lint, raised to the power of 0.5. According to previously cited data [3], C_d can be taken as 200 N/m. Then, for $m = 0.00012$ kg, the impact force will be $F_{\max} = 2.325$ N at $V_1 = 15$ m/s

In the absence of initial deformation ($X_0 = 0$) at the moment t after the start of the impact, according to the Dalamber principle, from the differential equation of motion [1, 2]:

and $F_{\max} = 3.875$ N at $V_1 = 25$ m/s. This force is quite large and, with a greater mass of seed cotton locks, can reach even higher values sufficient to cause intensive damage to the lint. The coefficient of dynamic stiffness for the lint's impact on the grate bar was not taken into account..

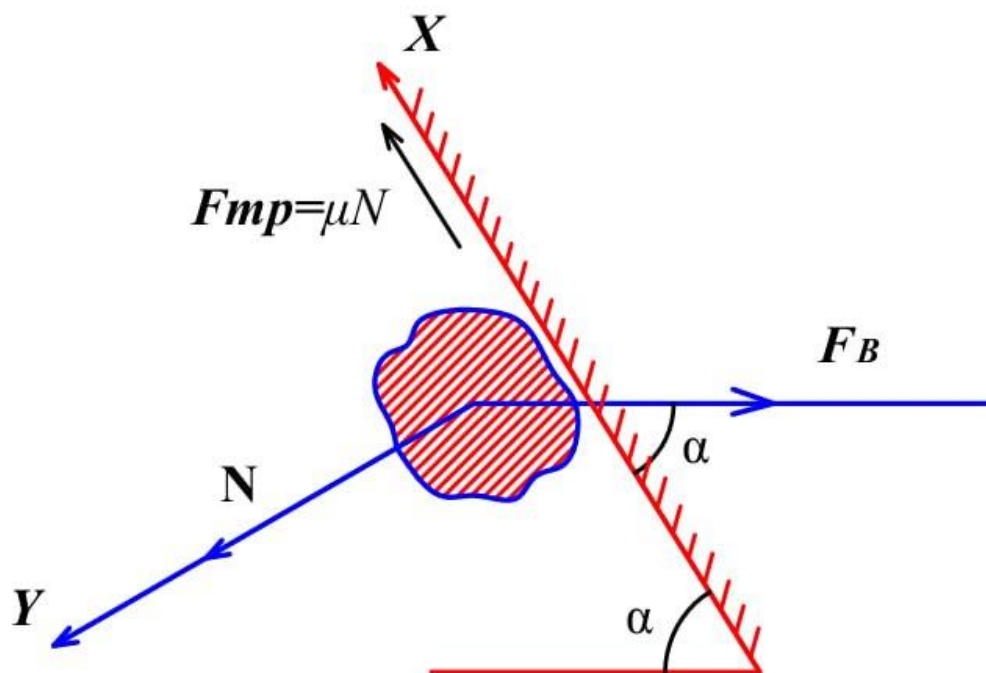


Figure 3. Effective forces during the impact of a lint particle on the pneumomechanical cleaner grate

The relationship (3) indicates the only way to reduce the impact force - controlling the initial speed of impact interaction. Reduction of the velocity V_1 can be achieved

$$V_1 = V_0 \sin \alpha \tag{4}$$

При $\alpha = \pi/2$ $V_1 = V_0$
 При $\alpha = \pi/0$
 $V_1 = 0,5 V_0$

and the impact force (excluding the friction force on the surface) decreases by half. In this case, formula (3) can be represented as ^

$$F_{max} = V_0 \sin \alpha \sqrt{C_d} m \tag{5}$$

for a "glancing" impact (at $\alpha = \pi/2$), which is less damaging than a frontal impact.

Obviously, reducing α to zero is impossible. By tilting the grate, it is possible to achieve values of $\alpha = \pi/12$ to $\pi/6$, which will reduce the impact force by a factor of 2 to 5. The choice of a system for feeding lint to the surface of the pneumomechanical cleaner's saw cylinder is also of considerable importance. If the grate is stationary, the lint will self-discharge from the grate provided that α is selected to account for the frictional force of the lint against the grate bar.

not only by reducing the velocity V_0 (lint movement) but also by correctly by choosing the orientation of the grate to the direction of the airflow, i.e., by choosing the angle $\alpha \beta \pi/2$, the magnitude of which depends on V_1 (Fig. 2, b).

Suppose a lint particle lands on the grate (Fig. 3), which is positioned at an angle α to the axis of the airflow.

Applying Amontons' law of friction [4], let us consider the conditions under which a fibrous particle slides along the surface of a grate. Since the friction in this case reaches the threshold value $F_{fr} = \mu N$, where μ is the coefficient of friction and N is the normal force exerted by the grate on the particle, we can derive the relationships between the forces F_{fr} and N and the aerodynamic force F_v , which presses the lint particle

against the grate, by projecting these forces onto the X and Y axes.:

$$\begin{aligned}\mu N &\leq F_b \cos \alpha \\ N &= F_b \sin \alpha\end{aligned}\quad (6)$$

The first inequality describes the movement (convergence) of particles. Dividing the first inequality

$$\mu = \operatorname{tg} \rho \leq \operatorname{tg} \left(\frac{\pi}{2} - \alpha \right) \quad (7)$$

where ρ is the angle of friction.

From this, it follows that

$$\alpha \leq \frac{\pi}{2} - \rho \quad (8)$$

In other words, the angle α should be as small as possible. With $\rho \approx \pi/4$ (45° , $\mu=1$), the worst-case scenario is when $\alpha < \pi/4$.

Thus, theoretically, the problem is solved by optimal selection of the filtering surface of the grate, with a decrease in the angle of inclination of which the impact force decreases and the conditions for feeding lint to the saw cylinder of the pneumomechanical cleaner are improved, as well as the self-discharge of lint, if the installation angle of the grate is chosen to be optimal..

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