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THE EQUATION OF MOTION OF COTTON FIBER IN THE CONDENSER

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Abstract: This article is discussed the equation of motion of cotton fiber in the condenser, describing the motion of a fiber in a condenser, equations can be used that take into account the forces acting on the fiber, as well as the characteristics of the airflow and the interaction of the fiber with the surface of the condenser, calculating the value of the cross-sectional area, showed the dependence of the distance traveled by the fiber on the time in the condenser at the specified parameters.

Keywords: cotton, separation, condenser, motion of fiber, main forces.

Introduction. The fiber condenser is an important element in the process of the cotton gin industry. Its main function is to condense and remove short fibers, fine debris and dust from cotton fiber to improve the quality of the final product.

The fiber condenser plays an important role in ensuring the quality of cotton fiber and the efficiency of its further processing, which makes it an indispensable element in the cotton gin industry [1-5].

To describe the motion of a fiber in a condenser, equations can be used that take into account the forces acting on the fiber, as well as the characteristics of the airflow and the interaction of the fiber with the surface of the condenser.

The condenser is used to separate the cotton fiber from the air, as well as to thicken the dissolved fiber mass and feed it into the press box. Condensers are also the simplest fiber cleaning machines, since part of the fine litter, dust and short fiber is released through their mesh drums with exhaust air.

There are a large number of different designs of condensers, but all have the same principle of operation and consist of a mesh drum, sealing and exhaust rollers. The fiber is removed from the mesh drum of the condensers by special removable rollers or under the action of centrifugal force.

Fiber condensers of the 5KV (8KV) grade operating in the cotton gin industry (Fig.1.) do not meet the requirements both in terms of performance and from the point of view of safety. When combined with jeans of the 5DP-130 brand, due to the discrepancy in their performance, frequent fiber slaughtering occurs. Since the introduction of condensers in cotton mills, dozens of fatal accidents have occurred when operators tried to eliminate slaughters.

High-speed capacitors have a number of significant disadvantages, which include:

- high aerodynamic drag;
- fiber ignition;
- unevenness of the outgoing canvas;
- frequent slaughtering;
- unsatisfactory service conditions leading to accidents.

Low-speed capacitors do not have the above disadvantages. They improve the quality of fiber and lint, and give a uniform canvas density.

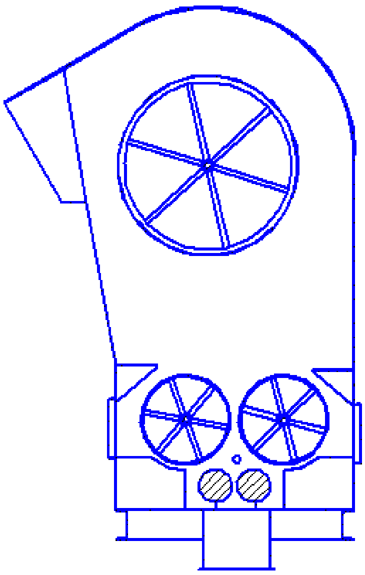

Fig.1. Cross section of the 5KV fiber condenser

We have developed an improved model of a new high-efficiency, safe fiber condenser with low-speed working bodies that ensure stable operation and low energy consumption. Compared to the current 5KV (8KV), it is characterized by simplicity of design and maintenance, small dimensions, low cost and reliability [6].

This installation (Fig.2.) consists of a housing 1 in which a mesh drum 2 is mounted, relative to which a movable sealing roller 3 and a fixed removable roller 4 are placed at a certain angle and gaps, mounted in a carriage 5, under which the unloading shaft 6 is located.

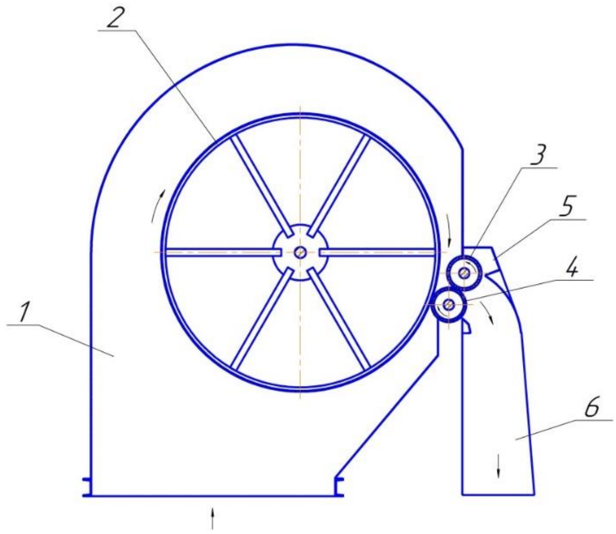

Fig.2. The technological scheme of the condenser

The housing is a welded metal structure providing dynamic rigidity of the entire installation. The mesh drum consists of a rigid frame and a mesh wrapped around the outer diameter. The sealing and removable rollers are grooved cylinders rotating relative to each other.

Due to the possibility of replacing the mesh of the mesh drum with a corresponding change in speed and aerodynamic modes, the condenser becomes universal, which ensures its smooth operation, both for fiber and lint. The performance of the proposed condenser will be at least 6 t/h in fiber and at least 1 t/h in lint.

Technical documentation is currently being developed and calculations have begun for the production of a prototype of a new condenser.

Methods. Let's consider the main forces acting on the fiber:

1. Gravity (mg): directed downward.
2. Aerodynamic force (F_d): directed in the direction of air movement.
3. Friction force (F_f): depends on the contact of the fiber with the surface of the drum.

In this case, the equation of motion of the fiber can be described using Newton's second law:

$$m\frac{d^2r}{dt^2} = F_g + F_d + F_f$$

where:

m — mass of the fiber,

r — position of the fiber in space,

F_g — gravity, $F_g = mg$,

F_d — aerodynamic for ce,

F_f — friction force.

The aerodynamic force is determined by the equation:

$$F_d = \frac{1}{2}\rho v^2 C_d A$$

where:

ρ — air density,
υ — the air flow velocity relative to the fiber,
C_d — coefficient of aerodynamic drag,
A — projection of the fiber area onto the flow direction.

The friction force depends on the normal force, which, in turn, can be related to aerodynamic and gravitational forces:

$$F_f = \mu N$$

where:
μ— coefficient of friction,
N — normal force.

When considering movement along the axis of the drum (for example, the x axis), the equation of motion can be simplified to a one-dimensional form:

$$m\,\frac{d^2x}{dt^2} = mg\,sin(\theta) + \frac{1}{2}\rho\upsilon^2 C_d A - \mu N$$

where:
θ — the angle of inclination of the condenser surface relative to the horizontal.

Given that the angle of inclination of the condenser surface θ is zero, the friction force μN will be zero. Also, we can assume that $N = mg$, since the normal force is equal to gravity in this case.

Results. Now we can write down the equation of motion of the fiber in a simplified form:

$$m\,\frac{d^2x}{dt^2} = \frac{1}{2}\rho\upsilon^2 C_d A$$

Substituting known values:
m = 1,5 kg (with a condenser capacity of 5.4 t/h),
g = 9.81 m/s² (acceleration of gravity),
ρ = 1.225 kg/m³ (air density under normal conditions),
υ = 13.6 m/s (air flow rate),
C_d = 2,15 (coefficient of aerodynamic drag)

Results. We can roughly calculate the value of the cross-sectional area A using the formula:

$$A = \frac{m}{\rho\upsilon^2 Cd} = \frac{1.5}{1.225*13.6^2*2.15} = 0.42\ m^2$$

Now let's substitute this value into the equation of motion of the fiber:

$$1{,}5\,\frac{d^2x}{dt^2} = \frac{1}{2}*1{,}225*13{,}6^2*2{,}15*0{,}042$$

$$\frac{d^2x}{dt^2} = 126{,}96\ m/s^2$$

This will give us an acceleration of the fiber movement in the condenser.

Integrating this time acceleration twice, we get:

$$\iint\frac{d^2x}{dt^2}\,dt\,dt = \iint 126.96^2\,dt\,dt$$

$$\int\frac{dx}{dt}\,dt = 126.96t + C_1$$

$$\frac{dx}{dt} = 126.96t + C_1$$

$$\int dx = \int(126.96t + C_1)\,dt$$

$$x = 63.48t^2 + C_1t + C_2$$

where C_1 and C_2 are the constant integrations that we need to define. To determine the constants C_1 and C_2, it is necessary to know the initial conditions of the fiber movement, for example, the initial velocity and position. If the initial velocity is $v_0 = 0$ (the fiber starts moving at rest), then C_1 =. Also, if the initial position is $x_0 = 0$ (the fiber starts moving from the zero coordinate), then $C_2 = 0$.

From these, a scheme for calculating the equation of motion (Fig. 3, b) was constructed using Carioles, elasticity, tensile and compressive forces in the condenser working zone (Fig. 1, a).

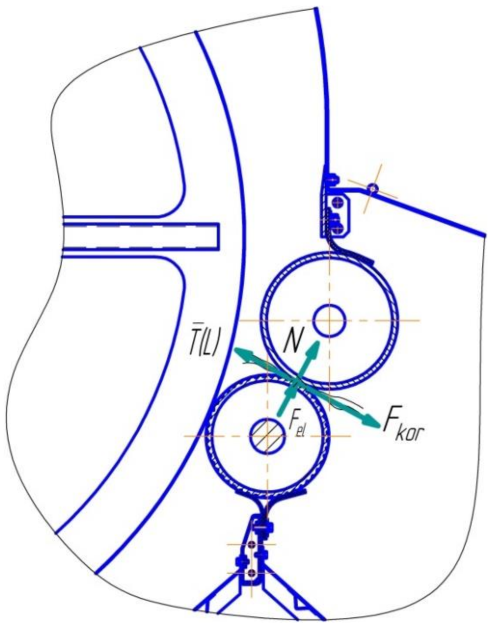

Fig. 3. Calculation scheme of the equation of motion of the fiber condenser

Discussion. Thus, the final equation of motion of the fiber will have the form:

$x=63.48t^2$

This equation shows the dependence of the distance traveled by the fiber on the time in the condenser at the specified parameters.

Conclusion. The equation of motion of a fiber in a condenser involves balancing gravity, aerodynamic forces, and friction. To accurately simulate this motion, it is necessary to take into account the geometry of the condenser, the properties of the airflow and the physical characteristics of the fiber.

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C O N T E N T S

PRIMARY PROCESSING OF COTTON, TEXTILE AND LIGHT INDUSTRY