Dynamics of Plane Motion of a Rigid Body

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Abstract: In general, the equations of motion of seeds on surface of the rib are compoled, the movement of seeds and the desent of seeds from the surface of the rib are studied. The obtained theoretical results are compared with the experimental results, the difference of which is up to 4%.

Keywords: Seed cotton, ginning of cotton, saw gin stand, roll box, seed roll, rib, concave and cotton seed.

1. Introduction

After leaving the raw roller, the seeds move along the seed comb towards the grate. With a 6 mm seed comb fingers, the clearance between the fingers and the saws for 130 saws is 5.525 mm, for 138 saws 5.025 mm, and for 156 saws 4.025 mm. Obviously, given the existing sizes of seeds, the bulk of them will stand out in the gap (30-35 mm) between the ends of the fingers of the seed comb and the grate, and falling on the grate, roll down along them (Fig. 1). Part of the seeds released onto the grate plane in the area of the seed comb is captured by the side surfaces of the saws and re-directed into the raw roller.

In the rarefied zone of the seed comb, 5-6% of seeds with increased fibrillation are released, the remaining 94-95% have normal and reduced fibrillation, and the seeds return to the working chamber not only with increased pubescence, but mainly seeds completely freed from fiber.

Some sorting of seeds according to the degree of their fibrillation, released in the area of the seed comb, is facilitated by the difference in the coefficients of friction of the seeds. Seeds with increased fibrillation have a high probability of returning to the working chamber.

Seeds of mass and radius move due to gravity along an inclined plane, which makes an angle with the horizon (Fig. 1). Seeds movement begins from a state of rest. The coefficient of friction of seeds sliding with the inclined plane in the section of the length is , in the section of the length is and on the remaining part of the inclined plane it is .

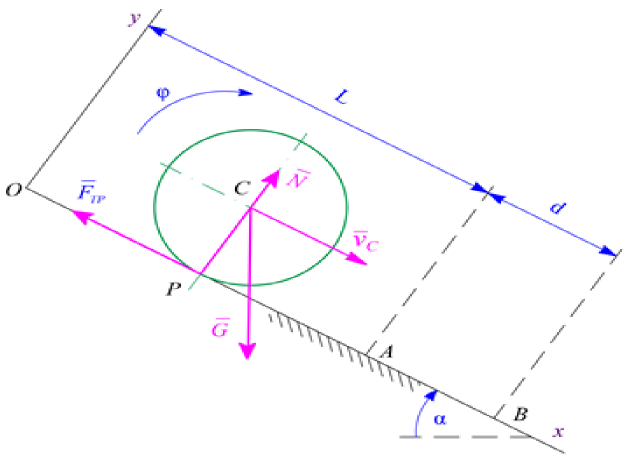


Fig.1. Seeds movement along an inclined plane

Let us direct the axis along the inclined plane in the seeds movement direction, and the axis - perpendicular to it.

The origin of coordinates is combined with the initial position of the body so that the axis passes through its center of mass. The angle is directed clockwise. The following forces act on the seeds (the rolling friction is ignored):

the force of gravity ; the normal response of the reference plane ;

the friction force resulting from the adhesion of seeds to the plane.

We apply the principle of constraints release and write down three differential equations of the plane motion of a rigid body:

$$\begin{aligned} m\ddot{x}_C &= mg\sin(\alpha) - F_{TP} \\ m\ddot{y}_C &= N - mg\cos(\alpha) \\ I_{Cz}\ddot{\varphi} &= F_{TP}\cdot r \end{aligned} \qquad (1)$$

The moment of inertia of seeds relative to Cz passing through its center of mass is:

$$I_{Cz} = \frac{1}{2} m\cdot r^2$$

According to the conditions of the problem, the initial conditions are as follows:

$$x_c\big|_{t=0} = 0 \qquad y_c\big|_{t=0} = r \qquad \phi\big|_{t=0} = 0$$

$$\dot{x}_c\big|_{t=0} = 0 \qquad \dot{y}_c\big|_{t=0} = r \qquad \dot{\phi}\big|_{t=0} = 0$$

Three second-order differential equations (1) contain five unknowns x_c, y_c, ϕ, N and F_{TP}. Taking into account $y_C = r = const$, we determine the normal response of the reference plane:

$$N = mg\cos(\alpha)$$

To determine the remaining unknown quantities, we consider two possible types of seeds rolling along an inclined plane: with sliding and without sliding. To describe the movement of seeds without slipping, we write down the known kinematic constraints equations.

Using this relation, from the first and the third equations of system [1] we find the forces of friction and acceleration of the center of mass of seeds:

$$\begin{aligned} F_{TP} &= \mu\cdot m\cdot g\cdot\sin(\alpha) \\ \ddot{x} &= (1-\mu)\cdot g\cdot\sin(\alpha) \end{aligned} \qquad (2)$$

$$\mu = \frac{I_{Cz}}{I_{Cz} + m\cdot r^2} = \frac{1}{1 + \frac{m\cdot r^2}{I_{Cz}}}$$

where

When seeds slide along an inclined plane, the friction force is equal to its limiting value $f|N|$ and after the substitution, the expression of force N takes the following form:

$$F_{TP} = F'_{TP} = f\cdot m\cdot g\cdot\cos(\alpha) \qquad (3)$$

and the acceleration of the center of mass of seeds and its angular acceleration are:

$$\ddot{x} = g\left[\sin(\alpha) - f\cos(\alpha)\right]$$

$$\ddot{\varphi} = f\,\frac{g}{r}\cdot\frac{1-\mu}{\mu}\cos(\alpha)$$

In this case, the velocity of the contact point of the body with the fixed plane P is zero ($v_p \neq 0$) and is directed towards the movement of the body, since the instantaneous center of velocities of seeds is displaced downward, perpendicular to the velocity of its center of mass.

An additional condition for the seeds movement with slipping can be written as:

$$F_{TP} \leq F'_{TP} \text{ or } \mu\cdot\sin(\alpha) \leq f\cdot\cos(\alpha)$$

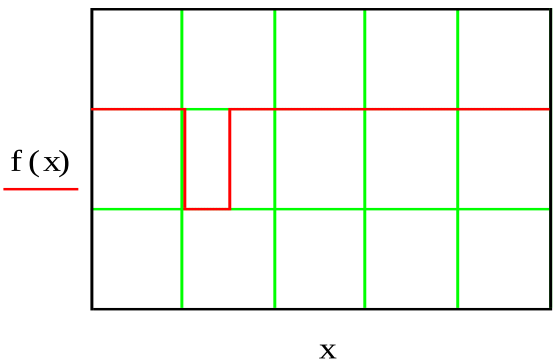
Finally, we get

$$f < \mu\cdot tg(\alpha)$$

Considering these two conditions, as well as expressions for the friction force in relations (2) and (3), it is possible to solve the problem.

The moment of inertia of seeds is calculated about the Cz axis passing through its center of mass; the coefficient μ is also determined.

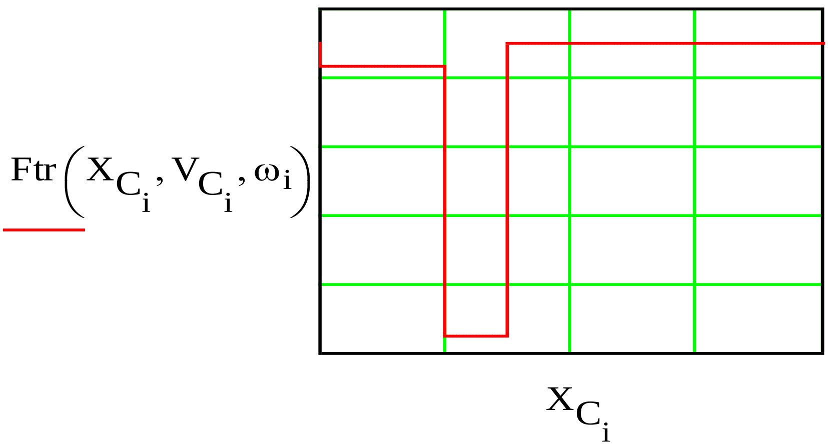
The law of variation of the coefficient of friction of seeds sliding along an inclined plane is written as a function of the coordinate of its center of mass and is shown on the graph.



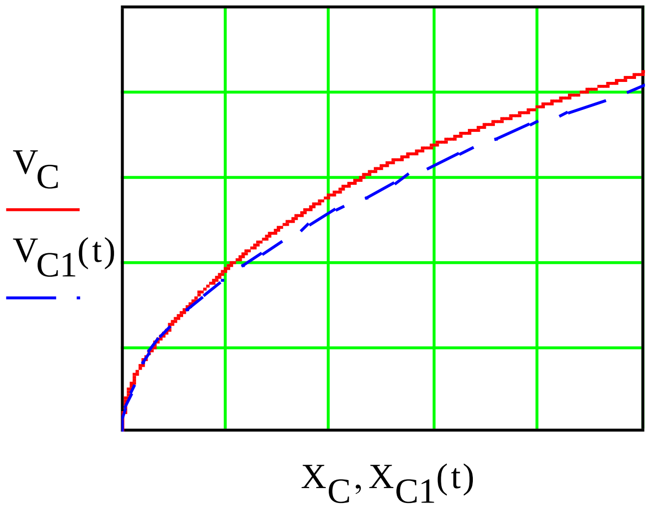
Using the expressions for the friction force [2] and [3], and the formulated conditions of motion with the seeds slippage, we set the expression for the friction force as a function of the kinematic parameters of the body.

Let us solve the first and the third differential equations of the system using the built-in function procedure rkfixed

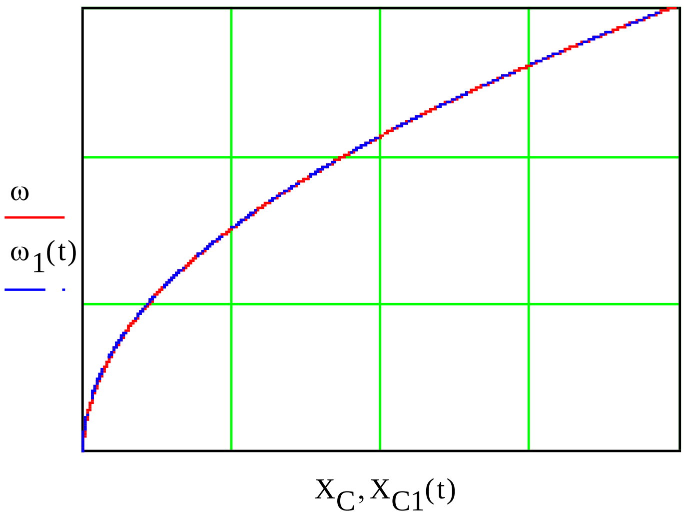
We plot a graph of changes in the friction force that occurs at the contact point of seeds with the plane, depending on the coordinate of the center of mass.



We plot a graph of velocity changes for the center of mass of seeds for a given problem, and when it moves without slipping.



We plot a graph of changes in the angular velocity of seeds for a given problem and when it moves without slipping.



2. Conclusion

The article research the movement of seeds on the surface of the new structures ribs in the working chamber of saw gin.

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