International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 9 No. 1 Sep. 2014, pp. 78-85

http://www.ijisr.issr-journals.org/

Experimental and theoretical studies of vibrational motion of raw cotton on inclined mesh surface

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ABSTRACT: In these research paper theoretical and experimental studies of vibrational motion of raw cotton in inclined mesh surface is considered. For cleaning small trash of raw cotton, new installation that has inclined mesh surface is used. The mathematical model of the motion of flying detachment in the line of plates with elastic elements is made up. Differential equations of motion of cotton's flying detachment are composed using the Lagrange II-kind. These equations are solved numerically by the program MAPLE-9.5. Results are obtained that is characterizing the movement law of cotton on an inclined mesh surface. Experimental study shows that the small particles of trash move on vibrating surfaces with different trajectories. This ensures separation and loosening and serves cleaning cotton from various trashes. Proposed installations provide vibration that is important element in the process of sifting.

KEYWORDS: cotton, fiber, differential equation, vibration, fraction, inclined mesh surface, plate, springs.

1 INTRODUCTION

During the process of raw cotton, the main indicator is yield of cotton fiber. On the saw gin it is almost impossible to achieve complete removal of the saw fiber. Since different trash located on the surface of raw cotton, and inside it, and have a degree of fiber adhesion. It is known that the trash is divided into large and small. Large trashes found on the surface of raw cotton and have poor adhesion with it, and small trash is deeply embedded in the mass of raw cotton. Their separation requires different external influences on fiber and raw cotton. For cleaning small trash of raw cotton, horizontal, vertical and various installations are used. In contrast to existing, the authors of this article propose a new installation (Fig. 1) having inclined mesh surface. After operation of drying drum, raw cotton is cleaned from small trash with the help of mesh surface [1],[2],[3] ,[7],[8].

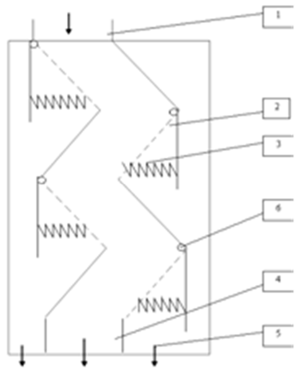

Figure-1. Proposed installation having inclined mesh surface.

2 THEORETICAL RESEARCH

Mesh surface is installed perpendicular to each other, having a certain angle from vertical. Oscillatory process of raw cotton is considered on an inclined mesh surface. Raw cotton is supplied from the feeder to the first mesh surface, moving on the mesh being subjected to vibration due to elastic relation of mesh with the base [4],[5],[6],[9],[10],[11,[12]. Scheme plate with elastic elements is shown in Fig. 2.

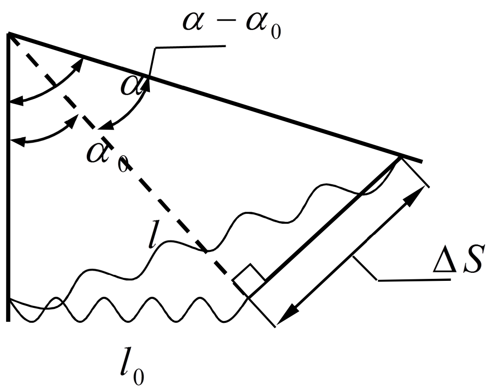

Figure-2.

OA-mesh plate

BA-elastic element (spring)

α_0 - Initial inclination angle from the vertical plate

α - Angle plate after elongation of the elastic element

l_0, l - The length of the elastic element to and after elongation

Δ - The length of the plate

ΔS - Absolute elongation of the elastic element

Ratio of triangles CCA and OBC define absolute elongation.

Δl - the elastic element

$$\Delta l = l - l_0 \quad \beta = \frac{\pi}{2} - \alpha + \left(\frac{\pi}{2} - \frac{\alpha - \alpha_0}{2} \right) = \pi - \frac{\alpha + \alpha_0}{2}$$

$$l_0 = a \cdot \sin \alpha_0 \quad \Delta S = 2a \cdot \sin \frac{\alpha - \alpha_0}{2}$$

From the theory of Cosines:

$$l = \sqrt{l_0^2 + (\Delta S)^2 - 2l_0 \cdot \Delta l_0 \cdot \cos \beta} \qquad (1.1)$$

After several transformations of (1) we get:

$$l \approx a(\sin \alpha_0 + \cos \alpha_0 \cdot \Delta \alpha) \qquad (1.2)$$

Or:

$$l = l_0 + a \cdot \Delta \alpha \cdot \cos \alpha_0 \Rightarrow \Delta l = l - l_0 \Rightarrow \Delta l = a \cdot \Delta \alpha \cdot \cos \alpha_0 \qquad (1.3)$$

Hence, the stiffness of elastic elements $\Delta l \le [\Delta l]$ must satisfy the conditions $\Delta l \le [\Delta l]$ (1.4)

3 MATHEMATICAL MODEL OF THE MOTION OF COTTON'S FLYING DETACHMENT ALONG THE PLATE WITH ELASTIC ELEMENTS

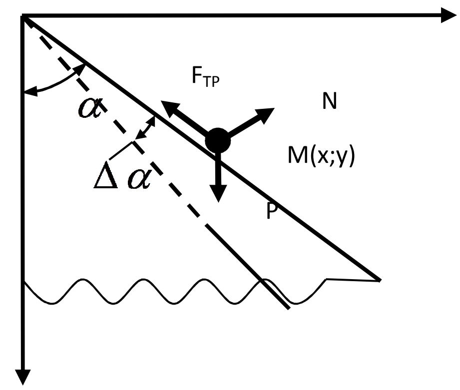

Figure-3

M – Cotton's flying detachment with weight – m

Coordinate points – **M**

$$\left.\begin{aligned} x &= s \cdot \sin \alpha \\ y &= s \cdot \cos \alpha \end{aligned}\right\} \qquad (2.1)$$

Where $S = OM$ - distance. Let $S_u \alpha$ - generalized coordinates of flying detachment - M. Acting forces and their projections on the axes OX and OY

a) The force of gravity:

$x_1 = 0$, $y_1 = mg$ (2.3)

b) The force of friction:

$$F_{fr} = [mg \sin \alpha + 2m\dot{S}\dot{\alpha}^2] \qquad (2.4)$$

Projections:
$$\left.\begin{aligned} F_{fr} &: x_2 = \mathrm{F_{fr}} \cdot \sin\alpha \\ y_2 &= -\mathrm{F_{fr}} \cdot \cos\alpha \end{aligned}\right\} \quad (2.5)$$

c) Elastic force of element:

$$\mathrm{F_{el}} = -\kappa \cdot a(\alpha - \alpha_0)\cos\alpha_0 \quad (2.6)$$

Projections:
$$\mathrm{F_{el}}: \left.\begin{aligned} \mathrm{x_3} &= \mathrm{F_{fr}} = -\kappa \cdot \mathrm{a}(\alpha - \alpha_0)\cos\alpha_0 \\ \mathrm{y_3} &= 0 \end{aligned}\right\} \quad (2.6)$$

Now we define the generalized forces acting on the flying detachment point M:

$$\mathrm{Q}_\alpha = (x_1 + x_2 + x_3) \cdot \frac{\partial x}{\partial \alpha} + (y_1 + y_2 + y_3)\frac{\partial y}{\partial \alpha} \text{ or}$$

$$\mathrm{Q}_\alpha = -\mathrm{S}\left[(\kappa\alpha \cdot \cos\alpha_0 + \mathrm{mg})\Delta\alpha \cdot \cos\alpha_0 + \mathrm{mg} \cdot \sin\alpha_0\right] \quad (2.7)$$

$$\mathrm{Q}_s = (x_1 + x_2 + x_3) \cdot \frac{\partial x}{\partial s} + (y_1 + y_2 + y_3)\frac{\partial y}{\partial \alpha} \text{ or}$$

$$\begin{aligned} \mathrm{Q_s} &= -\mathrm{mg} \cdot \mathrm{f} \cdot \sin\alpha_0 - \mathrm{mg} \cdot \mathrm{f} \cdot \Delta\alpha \cdot \cos\alpha_0 - 2\mathrm{m} \cdot \dot{\mathrm{S}}\dot{\alpha} \cdot \sin\alpha_0 - \\ &2\mathrm{m} \cdot \dot{\mathrm{S}} \cdot \dot{\alpha} - \kappa \cdot \mathrm{a} \cdot \Delta\alpha \cdot \cos\alpha_0 \cdot \sin\alpha_0 + \mathrm{mg} \cdot \cos\alpha_0 - \mathrm{mg} \cdot \Delta\alpha \cdot \sin\alpha_0 \end{aligned} \quad (2.8)$$

Movement of flying detachment point-M is prepared using the Lagrange equations II-kind.

$$\left.\begin{aligned} \frac{d}{dt}\left(\frac{\partial T}{\partial \alpha}\right) - \frac{\partial T}{\partial \alpha} &= Q_\alpha \\ \frac{d}{dt}\left(\frac{\partial T}{\partial \dot{S}}\right) - \frac{\partial T}{\partial S} &= Q_s \end{aligned}\right\} \quad (2.9)$$

Substituting (2.2) - (2.8) to (2.1), we obtain:

$$\left.\begin{aligned} & m \cdot S \cdot \ddot{\alpha} + 2m\dot{S}\dot{\alpha} + \alpha \cdot \cos\alpha_0(mg + \kappa \cdot \mathrm{a} \cdot \cos\alpha_0) + \kappa \cdot a \cdot \alpha \cdot \cos\alpha_0 \sin\alpha_0 - \\ & m\ddot{S} - m \cdot S \cdot \dot{\alpha}^2 + 2 \cdot m \cdot \dot{S} \cdot \dot{\alpha} \cdot (\sin\alpha_0 + \alpha \cdot \cos\alpha_0) + \kappa \cdot a \cdot \alpha \cdot \cos\alpha_0 \sin\alpha_0 - \\ & mg\left[\cos\alpha - f \cdot \sin\alpha_0 - \alpha(\sin\alpha_0 + f \cdot \cos\alpha_0)\right] = 0 \end{aligned}\right\} \quad (2.10)$$

The initial conditions:

when t = 0; $\alpha = 0$; S = S_0; $\dot{\alpha} = 0$; $\dot{S} = 0$ (2.11)

Nonlinear system of differential equations (2.10) with (2.11), are solved by a numerical method for the program MAPLE-9.5:

Initial data $l = 1м$, $y = 10\,\frac{м}{c^2}$, $m = 1кг$

Variant number 1: $\mathrm{f} = 0{,}1$; $\kappa = 5 \cdot 10^2\,МПа$; $\kappa_2 = 10 \cdot 10^2\,МПа$, $\kappa_3 = 15 \cdot 10^2\,МПа$, $\alpha_0 = \frac{\pi}{6}$; Figure 4a, 4b, 4c

Variant number 2: $\kappa = 5 \cdot 10^2$; $f_1 = 0{,}1$; $f_2 = 0{,}2$; $f_3 = 0{,}3$;

Fig. 5a, 5b, 5c

Variant number 3: $\kappa = 5 \cdot 10^2$; $f = 0{,}1$; $\alpha_1 = \frac{\pi}{6}$; $\alpha_2 = \frac{\pi}{4}$; $\alpha_3 = \frac{\pi}{3}$

Figure 6a, 6b, 6c

Curves: green - $\alpha_1 = \alpha(t)$, red - $\alpha_2 = \alpha_2(t)$, black - $\alpha_3 = \alpha_3(t)$

4 ANALYSIS OF RESULTS

Numerically solving the system (2.10) for given initial conditions, graphs are obtained characterizing change of inclined angle - $S(t)$, flying detachment moving along the length of the plate - as well as the relationship between the change in the angle α and displacement - S, in stationary mode.

Figure 4a, 4b, 4c - shows the variation, at different values the coefficient elasticity of the elastic element (curves 1,2,3). With increasing stiffness of elastic element, damped oscillation process occurs faster in time. The motion of flying detachment on the surface of the plate occurs almost equally regardless of changes in the stiffness of elastic element.

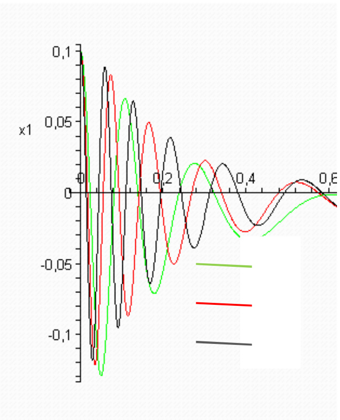

Figure-4a

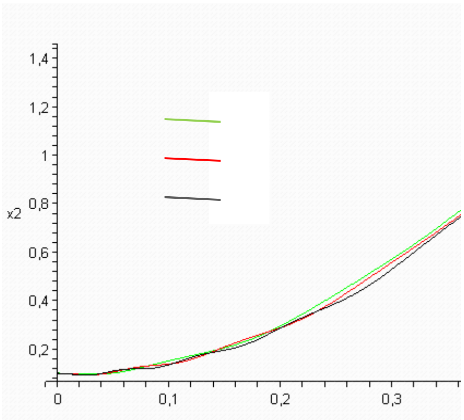

Figure-4b

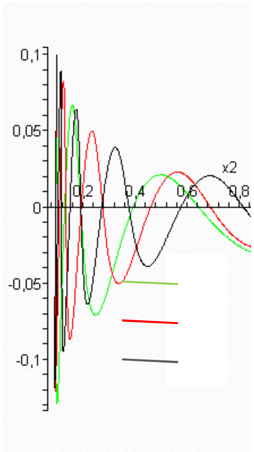

Figure-4c

Change in angle $\alpha(t)$ depending on the stiffness of elastic element, increasing the value - K corresponds to the phase of oscillation reduction.

Figure 5a, 5b, 5c, given change in inclination angle of plate - $\alpha(t)$ shift in flying detachment along the surface of the plate - $S(t)$ and the dependence for different values of the coefficient of dry friction f0 = 0,1; 0.2; 0.3 (curves 1,2,3).

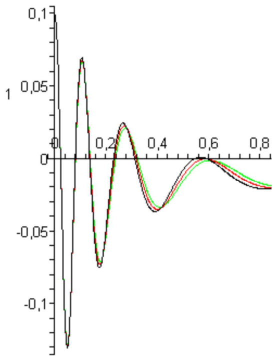

Figure-5a

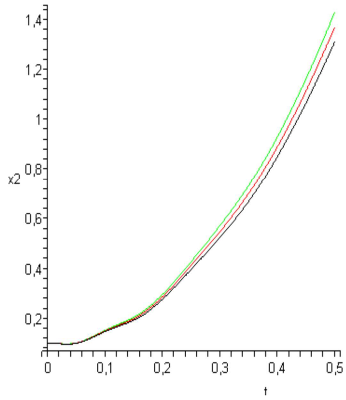

Figure-5b

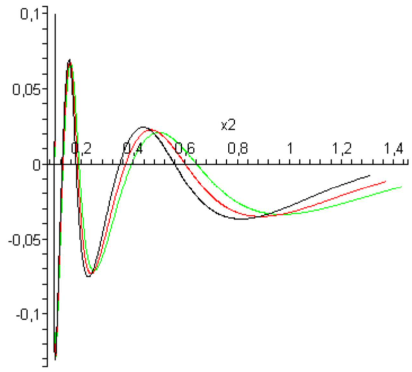

Figure-5c

From the graphs can be judged that they have a harmonic character. With the passage of time - t, change in $\alpha(t)$ - does not depend on change in coefficient of friction.

However, the movement of flying detachment along the length of the plate depends on the coefficient of friction. That is an increase - f, resulting in slower motion of flying detachment that corresponds to experimental data. Phases, the value - f, affects the oscillatory process of plate. Figure 6a, 6b, 6c - shows the character of the influence of changes in the initial angle $\alpha_0 = \frac{\pi}{6}; \frac{\pi}{4}; \frac{\pi}{3}$ (curves 1,2,3) to change in angle - $\alpha(t)$, shifted - $S(t)$ and $\alpha = \alpha(S)$;

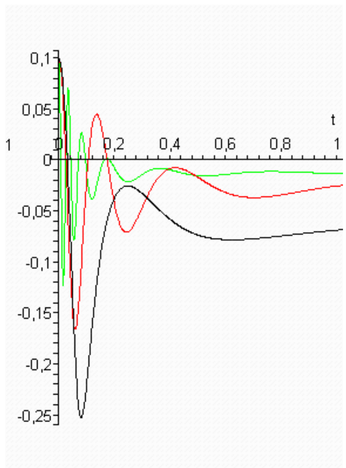

Figure-6a

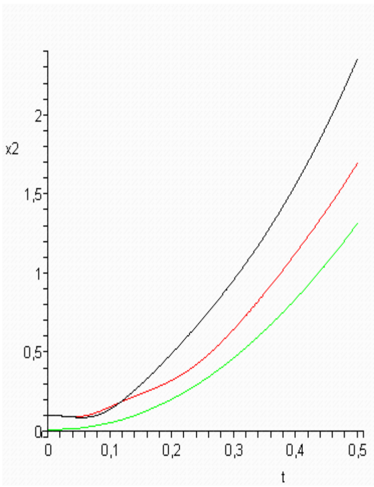

Figure-6b

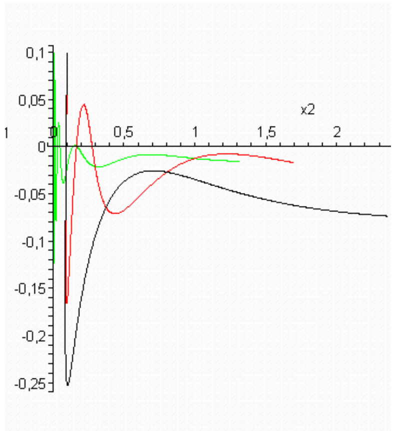

Figure-6c

From the analysis of the graphs it is evident that damped oscillation process occurs faster with an increase of the initial inclination angle.

Movement of flying detachment along the length of the plate also occurs faster with an increase of the initial angle of inclination.

Analyses of results show that the cotton's flying detachments move along the surface of the plate, obeying parabolic law, and change in the inclination damped harmonically.

5 EXPERIMENTAL STUDIES

In the technological process of cotton factories, after operation of drying drum significant portion of small trashes in composition of raw cotton remains. With the help of the installation, some small trash and various impurities are cleaned from raw cotton. As we know, process of cotton picking occurs in the cotton field, resulting in dirtiness of various fibers (with dust, sand, boxes, leaves, twigs, grass seeds). Separation small trash depends on connections the fiber with it. Sometimes cotton cleaning from trash in factories is very easy; sometimes it is a very complicated process. Therefore, in the process of cotton cleaning and ginning: saws, drums, and mesh surface are used, which have many shortcomings and inaccuracies. To eliminate these drawbacks, and on the basis of theoretical studies have been designed more simple and convenient design of new cleaning machine, which provides efficient cleaning of small trash without affecting the natural properties of cotton fiber and seed. Prospective new cleaner of cotton from small trash was set to technological process in CHINABAD cotton cleaning complex of Andijan "Pahtasanoat" and the experiments were conducted. This equipment is installed after the separator, cleaned cotton with help of air flow is sent to conveying pipeline. During the experiments, all the working parts of equipment were under constant supervision.

The experimental results are listed in Table 1.1. Experiments were carried out on raw cotton breeding varieties C-6524, sorts 1-2 and humidity 8% and 2.4-2.6.

Table 1.1 Vertically-cleaning installation

№	**Breeding sort**	**Industrial sort**	**Humidity**	**Dirtiness, %**		
				In the bulk	**After separator**	**After installation**
1	C-6524	1	8,2	2,4	1,95	1.76
2			8,8	2,5	1,98	1,77
3			8,8	2,6	1,92	1,74
1	C-6524	2	8,2	2,4	1,95	1,52
2			8,8	2,5	1,98	1,55
3			8,8	2,6	1,92	1,56

6 ANALYSIS OF RESULTS

Due to the elastic connection of the mesh surface in the direction of the y-axis, there is a harmonic oscillation that helps angles to rotate cotton relative to the axis, as the force of friction assists in separation from different trashes and cotton cleaning.

Experimental sample of vertical mesh situated at an angle 45 with the holes of the cells 3 is 10 mm, was installed in cotton cleaning factory processing 60 tons of raw cotton capacity per day.

Experiments were conducted on breeding varieties of cotton from the 6524 2-sort and Andijan 35 1-sort, with dirtiness of 12% and 4.5% humidity. Applying in this simple way of vibration, we have increased the cleaning effect by 5%. From this we can conclude that the vibration is playing a major role in the organization of the separating process and has the following main factors:

- Vibration is an important element in the process of sifting, because it provides intensive movement of particles from the holes, increases the probability passing particles of small fraction through the holes.

7 CONCLUSION

1. The mathematical model of the motion of cotton's flying detachment along the plate with elastic elements is prepared. Nonlinear system of differential equations describing the motion of flying detachment is solved by a numerical method with the program MAPLE-9.5.
2. It is shown by theoretical study that the process of damped oscillation angle plate is faster with increasing initial angle. Movement of flying detachment along the length of the plate also occurs faster with an increase in initial inclined angle.

3. As a result, using vibration along with converting frictional force to particles of small trash take effect motive forces which, under appropriate conditions also lead to an increase in the intensity of the separation process where vibrational forces provide conveying of raw cotton along the working surface and product separation from small trash to appropriate receivers.
4. Small trash particles with different properties are moving on a vibrating surface with different trajectories.

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