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Research on movement of cotton and heavy impurities in the working chamber of pneumatic cleaner.

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Abstract :
This research work deals with the theoretical investigation of the motion of cotton and heavy impurities in the chamber of pneumatic cleaner. We have developed universal pneumatic cleaner that cleans cotton from both the heavy, small and large trash. Differential equations are compiled on motion of mechanical system consisting of cotton and trash on the principle of D'Alamber. These non-linear differential equations with the corresponding initial conditions are solved numerically by the program MAPLE-9.5 on computer.

Keywords: cotton,technology,collector, speed of air, separator,mathematical model, nonlinear differential equations, mechanical system, Heaviside function, resulting graph

Introduction:

During assembly, processing, storage and supply of cotton in mass production, cotton falls into different foreign contaminants including minerals - dust, sand, pieces of earth, asphalt, bricks, stones of various sizes; metals - bolts, nuts, washers, screws, nails, pieces of metal parts and machinery, organic - dry and fresh leaves, boxes, branch, leaf and broken off part of the cotton and other plants, rag, rags and other objects caught in the territory of a cotton field, khirman, procurement centers in cotton cleaning factories. Their percentage ratio to the mass of cotton is called dirtiness of cotton. However, in practice, in determining the trash of cotton as a random phenomenon not taken into account in the presence of large cotton, including heavy impurities - stones, metal objects, although their content, particularly in low quality cotton reaches 3%.

Technology of primary processing provides cotton cleaning from trashes that are two types - small (the size of more than 10 mm) and large (greater than 10 mm) trash. However, cleaning cotton from heavy, especially solid content, regardless of their size in these cleaners cannot be due to the fact that cleaning processes take place in the hammer mode and such impurities cause cracking under the stress and strain of working machinery, as well as the revival of sparks might cause fire.

For this reason, it does not let solid impurities drop in the cleaning chamber and following technological machines that is provided by the use of linear cleaners –catcher of heavy impurities in pneumatic systems.

Analytical studies show that existing devices for cleaning cotton from heavy impurities do not completely meet the requirements of the industry because of the low rate of cleaning, resulting in passing the solid mass to technological machines and undesirable consequences. On this, scientists and experts in the field of cotton ginning and extensive studies are conducted on the development of unique cotton cleaner from heavy, solid impurities having a high cleaning effect.

We have developed universal pneumatic cotton cleaner that cleans cotton from both the heavy, small and large trash. Figure 1 shows a diagram of the new pneumatic cleaner where 1 - inlet, 6 – exit, 2 - working chamber of cleaner, 3 and 4 - reflective walls made of perforated material, 5 –trash collector.

In the operation of cotton cleaner air flow goes through the inlet 1 into the chamber2 of cleaner and a strikes the reflecting wall 3, it is shaken and slipped on the surface of the reflector 3 through the clearance between the reflectors 3 and4 removed from the chamber and through exit pipe 6 passes into pneumatic pipe. Heavy and large trashes that are separated from the cotton by gravity are falling downwards in trash collector 5.

Upon striking the cotton to the wall 3 small trash passes through the perforations and in the composition of air exits the chamber 2 occupying the upper layer flow. Cleaner is installed before the pneumatic separator. For this reason, small trashwill not be mixed with cotton and as part of the air coming out of the separator.

Some cotton particles when hitting the wall 3 can be separated from the general stream and fall down toward the trash collector. Such particles are mechanically hit the surface of the reflector 4, which is set at an angle smaller relative to the angle's natural slope not allowing cotton slip over the surface of the reflector 4 and carried down the air flow to the top and fed to aeromixture in the main part.

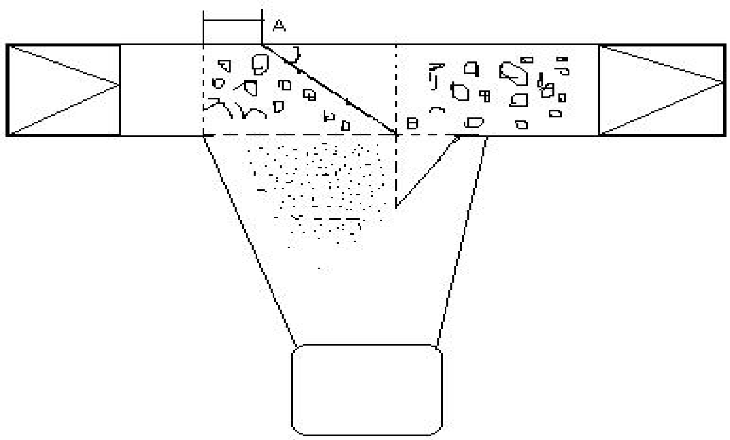


Fig.1.1. Diagram of Pneumatic cleaner

These studies are devoted to studying movement ofaeromixtureand its separate parts in the chamber of new cleaner in order to establish regularities of their movements and defining rational parameters pneumatic cleaner.

1. Theoretical research on motion of mechanical system consisting of cotton and trash in the chamber of pneumatic cleaner.

When cotton particles enter chamber of pneumatic cleaner, existing trash reduces their speed [1]. Separation of aero mixture starts by fraction. However, complete separation does not occur. Further, the particles strike the baffle wall.

1.1. Main physical and mechanical parameters.

We define the joint mass of cotton and trash:

$$M = m_{10} + m_{20} \quad (1.1)$$

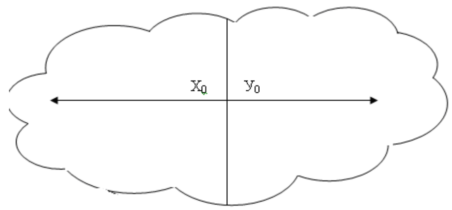
Where: m_{10}–(0.01kg) weight of cotton's flying fluff, m_{20}weight of dirty impurities. Supposing, there is a relationship between them:

$$m_{20} = nm_{10} \qquad (n=3\text{-}5)$$

x_1(t) –law of horizontal motion of cotton fluffs in the chamber of pneumatic cleaner.

x_2(t)–law of horizontal motion of trash in the chamber of pneumatic cleaner.

x_0 - (0.05m) -the length of the expansion of cotton fluffs at maximum air omission.



If fluff under the influence of the air flow reaches the maximum extension, the heavy mass is separated from it, and it begins to move independently.

In mathematical modeling of this process we use Heaviside function:

$$\eta = \eta(t) = \begin{cases} 1, \text{агар } t > 0 \\ 0, \text{агар } t < 0 \end{cases} \qquad (1.2)$$

The air speed when entering the working chamber of cleaner takes equal V_0. In the working chamber of its speed will be equal to:

$$V = \frac{L_0}{F_1}\left(\frac{m}{c}\right), \qquad (1.3)$$

Here: $$L_0 = V_0 \cdot F_0, \qquad (1.4)$$

V_0 –initial ,

F_0 –cross sectional area of the inlet pipe

L_0 –the initial air consumption

$L_0\left(\frac{m^3}{c}\right)$ $F_0\left(m^2\right)$ $V_0\left(\frac{m}{c}\right)$ (25-30m/sec,0.1m^2,)

Where: F_1- sectional area of the chamber cross-sectional area.

1.2. Mathematical model of process.

If fluff of raw cotton with a heavy litter consists of two-component system, then the motion of system until reflector plate can be described by the following mathematical model [2]**:**

a) Generalized weight: $$M = m_{10} + m_{20} * H(\tilde{x}) = m_{10}(1 + k * H(\tilde{x})) \qquad (1.5)$$

Here: $H(\tilde{x})$=1-η($\tilde{x}$); $$\tilde{x}_1 = \frac{x_1}{x_0} - 1; \qquad (1.6)$$

b) mass of heavy fractions: $$m_2 = m_{20} * \eta(\tilde{x}) = m_{10} * k * \eta(\tilde{x}); \qquad (1.7)$$

c) The active forces acting on pappus;

The aerodynamic driving force:

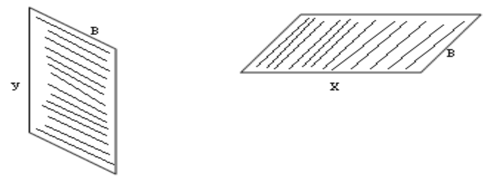
$$R_{x_1} = c_x * F_{\text{вер}} * \frac{\rho * (V - \dot{x}_1)^2}{2}; R_{y_1} = c_y * F_{\text{гор}} * \frac{\rho * (V - \dot{y}_1)^2}{2}; \qquad (1.9)$$

Gravity: $$G_1 = M * g \qquad (1.10)$$

Here: c_{x_1}, c_{y_1} - (0.3-0.5) drag coefficient of flying detachment, which are determined experimentally.

$F_{вер} = F_y$ - cross sectional area of the chamber in the vertical direction: $F_y = b * y;$

$F_{гор} = F_x$ - cross sectional area of the chamber in a horizontal direction: $F_x = b * x;$



$x_1(t)$-x_1(t) – law of horizontal movement of flying detachment cottonalong the axis Ox.

$y_1(t)$-law of the vertical movement of cotton flying detachment of the y-axis

The air velocity in the chamber: $V(t) = V_0 \frac{F_0}{F_y}$ (1.11);

d) Passive forces acting on the briefing:

The strength of the elasticity of cotton, resists the movement of the air flow:

$$F_{x_1} = k_x \eta(\bar{x}_1) * x_1 \qquad (1.12)$$

Here: k_x- the elasticity of cotton, $\bar{x}_1 = 1 - \frac{x_1}{x_0}$ - Heaviside function argument.

e) Active and passive forces acting on the heavy impurities:

The aerodynamic driving force:

$$R_{x_2} = c_{x_2} * S_0 * \frac{\rho_m * (V - \dot{x}_2)^2}{2}; R_{y_2} = c_{y_2} * S_0 * \frac{\rho * (V - \dot{y}_2)^2}{2};$$

Gravity: $G_2 = m_2 * g, m_2 = m_{20};$ (1.13)

Here: c_{x_2}, c_{y_2} - (0.5-0.7)drag coefficient of heavy impurities, which are also determined experimentally.

The cross sectional area of heavy impurities: $S_0 = \pi * r^2$, r -(0.003-0.007м)- radius of the cross section of heavy impurities. ρ - is the density of air (1.2kg / m3).

1.3 . Differential equations of the mechanical system, "Cotton + heavy impurities"

Differential equations of the mechanical system, "Cotton + heavy impurities" will be on the principle of D'Alamber:

$$\begin{cases} M * \ddot{x}_1 = R_{x_1} - F_{x_1} \\ M * \ddot{y}_1 = -R_{y_1} + G_1 \end{cases} \qquad (1.14)$$

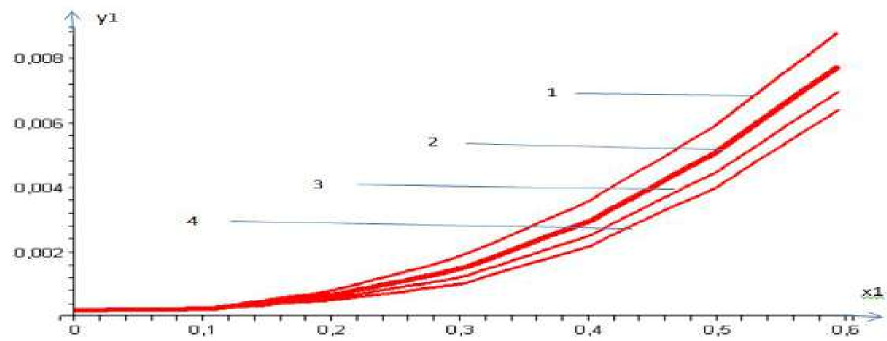
$$\begin{cases} m_2 * \ddot{x}_2 = R_{x_2} \\ m_2 * \ddot{y}_2 = -R_{y_2} + G_2 \end{cases} \qquad (1.15)$$

or

$$\begin{cases} M * \ddot{x}_1 = c_x * F_{\text{вер}} * \frac{\rho*(V-\dot{x}_1)^2}{2} - k_x\eta(\bar{x}_1) * x_1 \\ \quad M * \ddot{y}_1 = -c_y * F_{\text{гор}} * \frac{\rho*(V-\dot{y}_1)^2}{2} + M * g \end{cases} \quad (1.16)$$

$$\begin{cases} \quad m_2 * \ddot{x}_2 = c_{x_2} * S_0 * \frac{\rho_m*(V-\dot{x}_2)^2}{2} \\ m_2 * \ddot{y}_2 = -c_{y_2} * S_0 * \frac{\rho*(V-\dot{y}_2)^2}{2} + m_2 * g \end{cases} \quad (1.17)$$

This shows that the mathematical model of the mechanical system, "Cotton + heavy impurities", described by a system of nonlinear differential equations 2 - order. These equations due to their nonlinearity is solved numerically program MAPLE-9.5.



With this program, we received appropriate mechanical system motion graphics "Cotton + heavy impurities", which are presented below.

Figure 1.2 The law of vertical movement of cotton and heavy impurities.$m_{10} = 0.025$кг- weight of cotton flying detachment,$m_{20} = nm_{10}$- the mass of the heavy impurities,1-n=0.25;2-n=0.5;3-n=0.75; 4-n=1; y1(m) ,x1(m) .

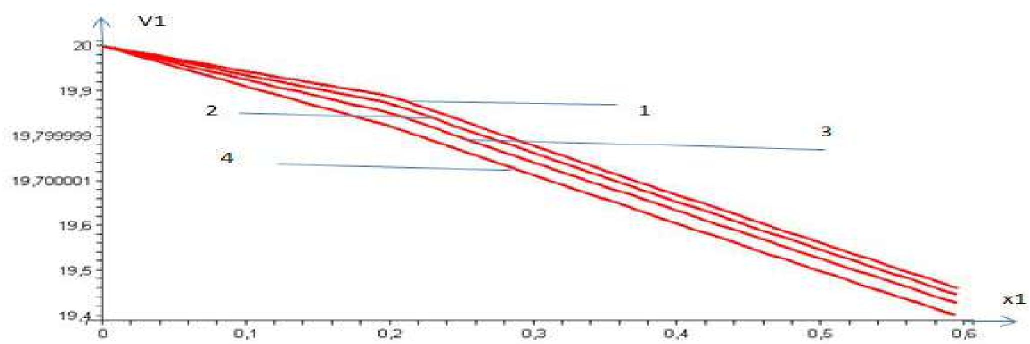


Fig. 1.3. Laws change speed flying detachment of cotton with heavy impurities in the horizontal axis.

$m_{10} = 0.025$кг weight cotton flying detachment with heavy impurities.1-n=0.25;2-n=0.5;3-n=0.75;4-n=1;v1(m/s), x1(m) .

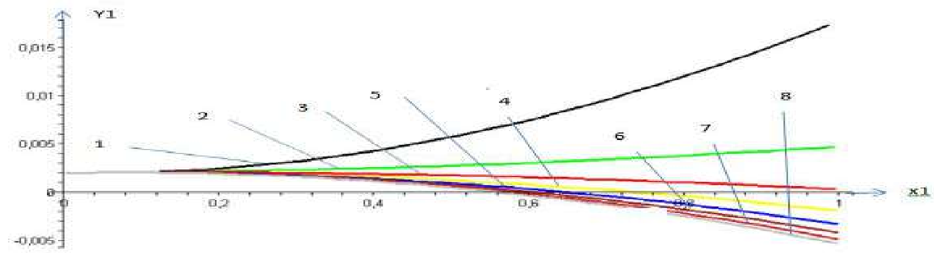


Fig. 1.4. The law of change of speed briefing cotton with heavy impurities on the vertical axis. briefing weight cotton with heavy impurities. 1-n = 0.25; 2-n = 0.5; 3-n = 0.75; n-4 = 1; v1 (m / s), x1 (m).

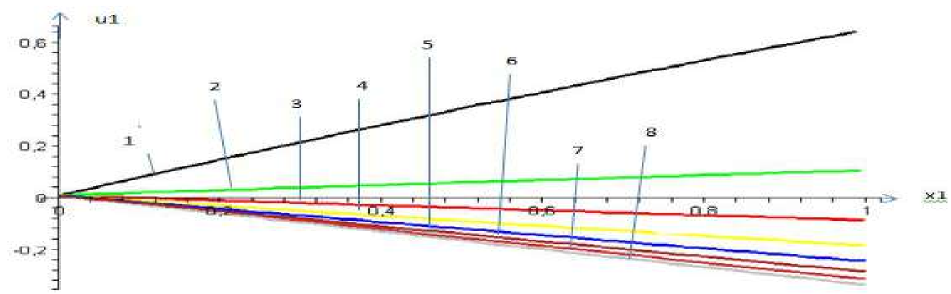


Fig. 14. The law changes the speed of heavy impurities in the vertical axis. . - Extra weight of heavy impurities. 1-n = 0.25; 2-n = 0.5; 3-n = 0.75; n-4 = 1; u1 (m / s), x1 (m).

1.4. Analysis of the results

The graphs show that cotton and heavy particles of impurities in a chamber within the cleaner 0.005 sec tested on a horizontal plane a distance of 10-15 cm as a single system (see. Fig. 1.2-1.3). Then, the expansion chamber causes the volumetric expansion of the system, "Cotton + heavy impurities". As a result of the heavy impurities are separated from it, as can be seen from Fig. 1.2, where the trajectory is upward cotton flying detachment character. From Fig. 1.3 can also be observed that the horizontal velocity component cotton flying detachment when entering the camera falls cleaner. The resulting graph shows also that the speed reduction is not 10-13%. Slow down flying detachment increasing their mass shows the adequacy of mathematical models. Partially separated from heavy impurities cotton flying detachment continues to move further along the working chamber cleaner. Fig. 1.4 and 1.5 are presented graph moving speed and heavy impurities vertically, which show that the heavier particles begin to settle in the lungs and sorosbornik particles continue to move forward

2. Study cotton flying detachment movement along the inner surface of the baffle plate.

Movement of cotton flying detachment in the working chamber of the cleaner to pass a path equal to a, and strike the reflecting plate AB angled α- (45-60gr) about a horizontal axis. However, some particles are in shadow may extend past the plate without touching it. A main part after the impact, because ductility is not separated from the plate surface and starts moving on its surface toward its lower extremity. It does not take into account the impact the process of flying detachment with the plate due to the elastic properties of cotton.

2.1. A mathematical model of the process of moving particles on the surface of the reflector

In Figure 2.1 is a diagram of movement of particles on the surface of the reflector. Let the movement poishodit without departing from point A to B, and then continue to the horizontal movement of the particles.

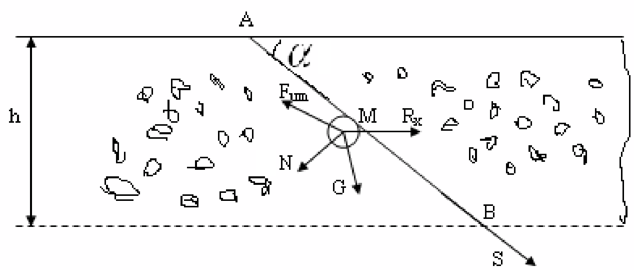


Figure 2.1

Active and passive forces acting on a particle:

The strength of the aerodynamic pressure:

$$R_x = \frac{\rho * V^2}{2}; \qquad (2.1)$$

$$R_{xs} = R_x \cos\alpha; \qquad (2.2)$$

The strength of the flying detachment weight: $G_s = G\sin\alpha; G = m_{10}g; m = m_{10}$ (2.3)

Normal force plate at briefing: $N = R_x \sin\alpha;$ (2.4)

The force of friction pile: $F_{\text{ишк}} = f_0 N = f_0 R_x \sin\alpha$ (2.5)

Here: f_0 –coefficient of friction between the plate and flying detachment. (0.001-0.01)

2.2. Differential equations studied mechanical system

Operating cotton flying detachment movement towards AS on the principle of a D'Alambera. In this case, the differential equations of the mechanical system can be written as:

$$m\ddot{s} = \sum F_{si} \qquad (2.6)$$

Here: $s = s(t)$ - the motion of flying detachment of cotton on the surface of the plate;

$$\sum F_{si} = R_{xs} + G_s - F_{\text{ишк}} = \frac{\rho V^2}{2}(\cos\alpha - f_0 \sin\alpha) + Mg\sin\alpha \qquad (2.7)$$

The initial conditions: $t = 0;\ s(0) = 0,\ \dot{s}(0) = V_0(0) = 0.$ (2.8)

(2.7) set in (2.6):

$$\ddot{s} = \frac{\rho V^2}{2m}(\cos\alpha - f_0 \sin\alpha) + g\sin\alpha \qquad (2.9)$$

(2.9) is the differential equation of motion flying detachment of cotton on the surface of the plate. If the velocity of the air in the working chamber $V = V_0 \cos\alpha$ then (2.9) takes the form of differential equations:

$$\ddot{s} = \frac{\rho}{2m}(V_0 \cos\alpha)^2(\cos\alpha - f_0 \sin\alpha) + g\sin\alpha \qquad (2.10)$$

Further, briefing cotton continues to move after the plate AB in between IRR and this movement is characterized by non-linear differential equations of the form:

$$\begin{cases} m * \ddot{x}_2 = R_x = c_x * F_p * \frac{\rho_m * (V_g - \dot{x})^2}{2} \\ m_2 * \ddot{y}_2 = -c_y * F_p * \frac{\rho * (V_v - \dot{y})^2}{2} + m * g \end{cases} \qquad (2.11)$$

Initial conditions: $t = 0 : x(0) = y(0) = 0;$ (2.12)

$$\begin{cases} \dot{x}(0) = U_m \cos\alpha \\ \dot{y}(0) = U_m \sin\alpha \end{cases} \qquad (2.13)$$

The cross section of flying detachment cotton: $F_p = \frac{\pi d^2}{4}$.

Since Differential Equations (2.10) (2.11) nonlinear can be solved with the initial conditions corresponding numerical method for the program MAPLE-9.5 on your computer. Further, the results presented in graphical form.

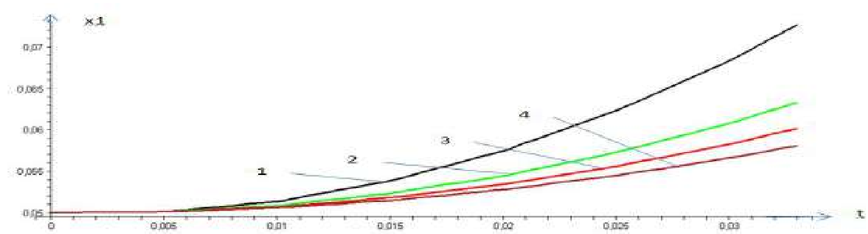


Figure 2.2. The law of motion flying detachment cotton at the inner surface of the plate over time. Mass of flying detachment cotton - 1-к=0.02, 2-к=0.04, 3-к=0.06, 4-к=0.09

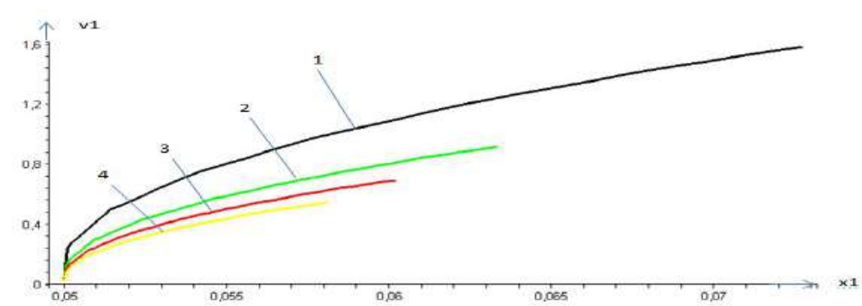


Figure 2.3. The variation speed flying detachment cotton on the inner surface of the plate according to the coordinate x1. K=m_{10} (kg) mass of flying detachment cotton - 1-к=0.02, 2-к=0.04, 3-к=0.06, 4-к=0.09

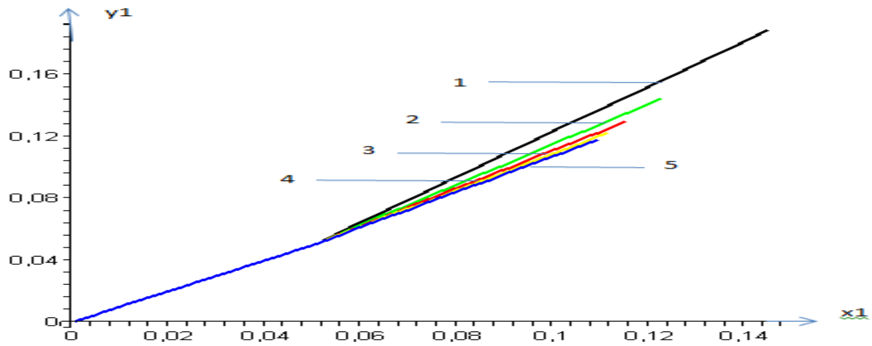


Fig.2.4. the law of motion flying detachment cotton interval IRR depending on coordinates x1. Weight of cotton flying detachment K=m₁₀ =0.0103 (kg) to 1-к, 2-2к, 3-3к, 4-4к, 5-5к.

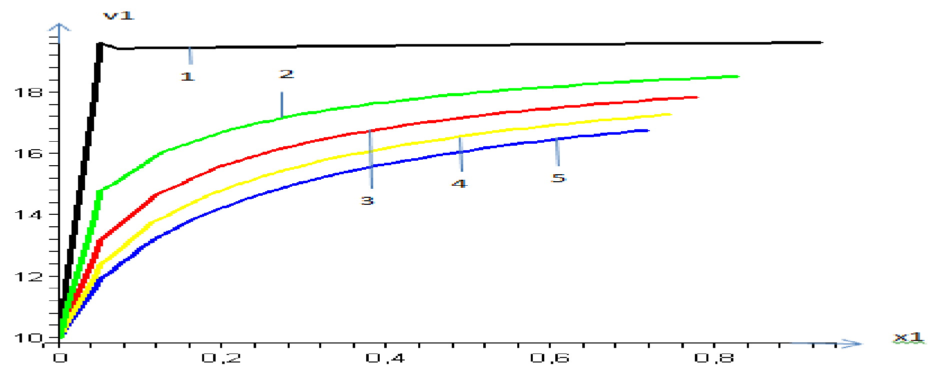


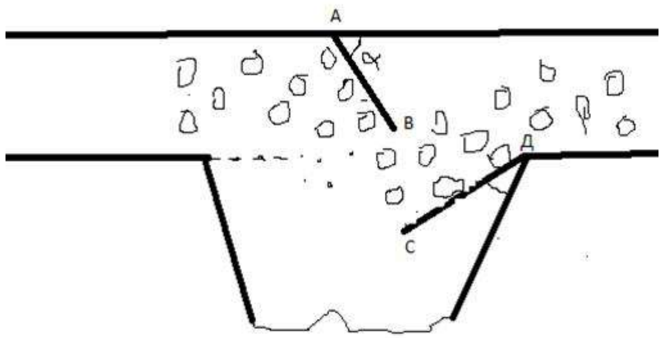
Figure 2.5. The law of motion flying detachment cotton VSD interval in the horizontal direction according to the coordinate x1. Weight of cotton flying detachment K=m_{10} =0.0103 to 1-к, 2-2к, 3-3к, 4-4к, 5-5к.

2.3. Analysis of results.

Cotton flying detachment after the passage of a distance and hit the plate AB begins to move across the surface of the plate. The relevant laws of motion are shown in figure 2.2-2.3. Charts show that (Figure 2.2) lighter fraction (a) relatively heavy will cover the distance AB and continue to move in the gap VSD (Figure 2.3). The laws of motion cotton flying detachment interval IRR is presented in figure 2.4-2.5. . waste bin interval VVD, flying detachment cotton ability to make some (short) time stuck in the air, and then continue to move vertically, which are illustrated in the graphs (fig. 2.4-2.5). In figure 2.4-2.5 cotton flying detachment moves vertically, horizontally speed depending on the coordinate x1. In Figure 2.5 we can see how to continue to move flying detachment cotton after an equilibrium condition. In this case, the heavy impurities are deposited in waste bin before reaching the outlet fall to the surface of the wafer CD and rolled on its surface down into the waste bin.

3. Theoretical study of motion of flying detachment on the cotton surface of the plate CD.

Heavier cotton flying detachment after hitting the wall AB is not carried away by the air flow can fall down - on the surface of the wafer CD and continue to move on its surface (Figure 3.1).



3.1. Mathematical model of motion of cotton flying detachment on the surface of the plate CD.

In this case, cotton flying detachment will operate the following forces:

$R_x = mk_p(v_x - \dot{x}(t))^2$–aerodynamic force that causes movement of flying detachment;

$G_p = mg$ - weightforcecottonflyingdetachment; $F_{\text{ишк}} = f_0 N = f_0 G_p \cos\theta$ - friction between the cotton and the plate; θ–the angle of inclination of the plate relative to the horizontal axis CD; v_x–air velocity; xCy – Descartes coordinate system; k_p – shift factor cotton at the wafer surface.

Operating cotton flying detachment movement toward LEDs on the principle of a D'Alambera. In this case, the differential equations of the mechanical system can be written as:

$\ddot{x} = mk_p(v_x - \dot{x}(t))^2 - g(f_0 \cos\theta + \sin\theta)$(3.1)

The relative speed of flying detachment we denote: $u(t) = v_x - \dot{x}(t)$ (3.2)

Then$\dot{u}(t) = -\ddot{x}(t)$, where we write(3.1) next

form :$\dot{u}(t) = k_p\big(u(t)\big)^2 - g(f_0 \cos\alpha + \sin\alpha)$ (3.2)

We introduce the notation$c^2 = \frac{g(f_0 \cos\alpha + \sin\alpha)}{k_p}$and rewrite (3.2):

$\dot{u}(t) = k_p(c^2 - (u(t))^2)$ (3.3)

Initial conditions: $t = 0 : x(0) = 0; u(0) = v_0$ (3.4)

Since the differential equation (3.3) is non-linear, then his decision to look for numerical methods in a computer program MAPLE-9.5 with the appropriate initial conditions.

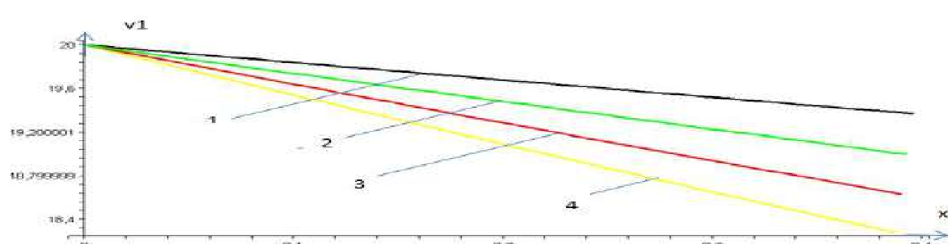


Figure 3.2. The variation speed flying detachment cotton at the wafer surface as a function of STO coefficient flight. **1-n = 0.1; 2-n = 0.15; 3-n = 0.2; n-4 = 25;**

3.1. Analysis of the results:

Heavier flying detachment cotton after hitting the wall AB is not carried away by the air flow can fall downwards - to the surface of the plate and diabetes continues to move along its surface. The results show that (Figure 3.2) with increasing shear rate of speed in the direction DM cotton reduced. However, from the results, it became known that this decrease does not exceed 20% while flying detachment does not leave the surface of the plate CD. The graphs learned also that with increasing angle of inclination of the plate relative to the horizontal axis velocity cottoncotton also increases. I.e., cotton flying detachment continues its movement along the plate surface diabetes without load surface.

4. Theoretical studies of shock interaction of heavy impurities from the surface of the plate AB.

4.1. Математическая модель процесса

A mathematical model of the process heavy impurities consider a material point of mass $m = m_{20}$. Let impurities strike the wall AB at a speed V_m.

How to look at the impact with respect to the coordinate axes xOy (Figure 4.1).

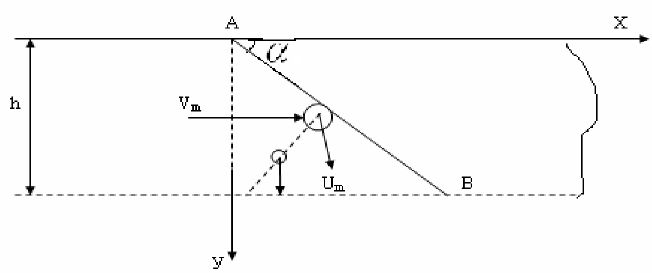


Figure 4.1

Let the point M of impact of the particle on the wall. If the wall is absolutely solid and smooth, the angle of impact is equal to the angle of reflection. Then the speed before and after the impact will be correspondingly equal. Since AB reflector is fixed, its speed will be zero. Let the coefficient of restitution is

$$k = -\frac{U_m}{V_m} \qquad (4.1)$$

Here, $k = 0.5 \div 1$. If the coefficient of friction between the deflector and the particle is equal to f. The dependence of the velocity [3]

$$|U_m| = |V_m| k \frac{\cos\alpha}{\cos\beta} \qquad (4.2)$$

Heavy impurities after the impact will be moving on a plane xMy with an initial velocity U_m. In this case, the heavy impurities will act forces:

Aerodynamic pressure on the x, y,

$$R_x = c_x * S_0 * \frac{\rho m * (V - \dot{x})^2}{2}; R_y = c_y * S_0 * \frac{\rho * (V - \dot{y})^2}{2}; \qquad (4.3)$$

Gravity impurities G$= m_{20} * g$;Where the cross-section of the impurities: $S_0 = \frac{\pi d^2}{4}$.

We form the differential equations of motion of heavy impurities on the principle of D'Alembert

$$\begin{cases} m * \ddot{x} = R_x \\ m * \ddot{y} = -R_y + G \end{cases} \quad (4.4)$$

Or

$$\begin{cases} m * \ddot{x} = R_x = c_x * S_0 * \frac{\rho_m * (V - \dot{x})^2}{2} \\ m_2 * \ddot{y} = -c_y * S_0 * \frac{\rho * (V - \dot{y})^2}{2} + m * g \end{cases} \quad (4.5)$$

Initial conditions: $t = 0 : x(0) = y(0) = 0;$ (4.6)

$$\begin{cases} \dot{x}(0) = U_m \sin \alpha \\ \dot{y}(0) = U_m \cos \alpha \end{cases} \quad (4.7)$$

Since These equations are nonlinear, too, their decision to produce numerically in a computer program MAPLE-9.5.

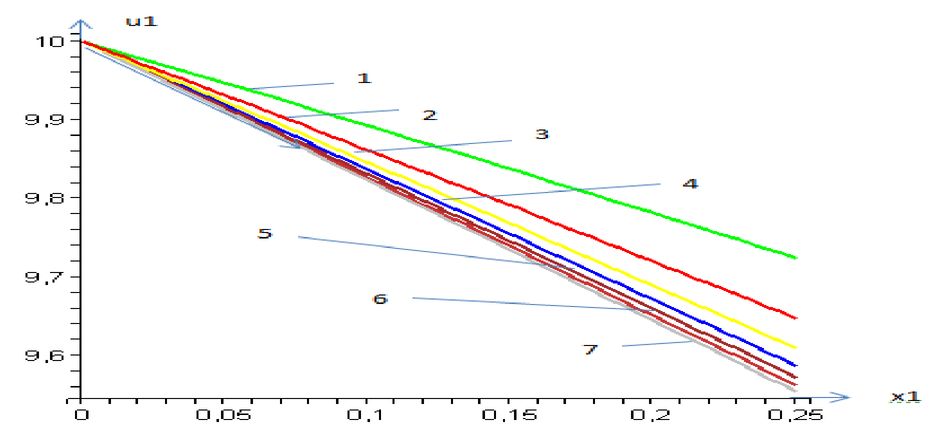


Figure 4.2.the variation of the speed heavy impurities depending on the coordinate x1. m_{20}=0.02k(кг) the mass of the heavy impurities.1-к=0.25;,2-к=0.5;3-k=0.75;4-k=1;5-k=1.25;6-k=1.5;7-k=1.75;

4.2. Analysis of results:

Heavy contaminants under the action of the air flow is separated from the cotton hit the wall AB. How to strike a blow consider a rigid body with a flat surface. For this, you can take the impact angle equal to the angle of rebound. After impact, the heavy impurities under its own weight to be moved down to the dust-collecting. It can be seen from Figure 4.2, which shows the change of velocity over time and the coordinate x1. Impurities weighing 20 grams or more are more likely loss in the dust-collecting. At the same time, the rate of impurities in the coordinate x1 remain constant (4m /s -5m/s) and rate of impurities in the coordinate y1, which corresponds to the side of the waste container is raised.

Conclusions:

1. The mathematical model of the motion of the particles of cotton, having in its composition heavy impurities in the chamber pneumatic cleaner to baffle plate AB, on the surface of the latter and in between VSD, on the surface of the plate CD.
2. The analysis of mathematical models and numerical solution method, which are presented in graphical form.

3. It is found that due to the volume expansion of the particles as they move cotton chamber pneumatic cleaner separates heavy impurities. Part of the heavy impurities fall into the waste container before hitting the baffle wall AB, and the rest - for any subsequent processes.

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