Pol. J. Environ. Stud. Vol. 32, No. 4 (2023), 3007-3014
DOI: *10.15244/pjoes/163341* ONLINE PUBLICATION DATE: 2023-05-10

Original Research

Theoretical Researching of Particle Movement in Cleaning Zone of Dust-Arrester

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Received: 15 January 2023
Accepted: 17 April 2023

Abstract

In the article movement trajectory of the particles in dust-arrester intended for cleaning of perfected air in technological process of cotton cleaning industry was given. It is known that the composition of perfected air in cotton-cleaning industry is directly connected with efficiency of its cleaning. The percent mineral and organic material in the composition of cotton passion depends on the technological processes. Revision productivity using any vacuum cleaner instrument depends on the specifics of passion, not review their types. It is possible to say that, it depends on morphological characteristic of passion, on the form, chemical composition, density, comparative surface, adhesion, spilt and poring and moisture it. In existing technological process of primary cotton processing the perfected air with various components of dust particles is allocated. The air speed admitted info the camera of dust-arrester signifies in the cleaning process of dusty air. In details, the correlation between the speed of particle eddy and movement trajectory of these particles in the aggregate is not completely researched. In this regard, air purification from fibrous impurities is relevant.

Keywords: cotton, fiber, dust, dust collector, mineral dust, organic dust, environmental

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Introduction

In the world, it is becoming important to carry out large-scale research work to improve the technique, technology and their scientific substantiation of the primary processing of cotton. In particular, the development of the scientific foundations of cotton transport mechanisms and their multi-thread movement, the determination of the parameters of the mechanisms for extracting cotton from the air, the development of patterns of movement of dusty air in pipes and the technology for its purification, the determination of the operating mode, parameters and indicators of the working bodies of the dust collector. Therefore, the creation of an effective technology for cleaning the air from the dust of cotton ginning enterprises is one of the important issues.

In recent years, in Uzbekistan and in countries where cotton industry is developed, special attention has been paid to the production of high-quality completed products that ensure competitiveness in the world market based on the improvement of technologies and technologies of the cotton and textile industries, and deep processing of raw cotton [1-5].

Today, the cleaning industry not only receives the purified product in its raw form, but also stores and prepares it during the drying process. They also clean and improve the technological process of the pat product in its raw form. At the same time, various problems also arise to improve the technological process of reducing dusting and cleaning atmospheric air. [6-11].

It is no more difficult to retain dust than toxic gas. But at the same time, the efficiency of dust capture is ensured, depending on the characteristic structure of the dust collecting equipment. Primary processing shows that there are three types when processing cotton products in raw form. They consist of the following fractions:

1. The mineral particles of passion in the size of 0.1-0.2 mm;

2. The grinders piece of cotton plant, which consists of from (the boll of the pat, pedicel, stalk, sheet), in size of from 0,1 till 0.315 mms;

3. The short filament of the miscellaneous of length - from most big length till 10 amounts, greater particles till 0,4 mms;

There are broadly used from vacuum cleaner instrument in the processing in agricultures in the purpose of the defogging heavy elements [12-15].

The creation of favorable working conditions at cotton ginning plants is inextricably linked with the purification of dusty air from technological processes into the atmosphere. Dusty air from processes is bad if it is vented directly to the atmosphere. As a result, the number of occupational diseases will increase at enterprises and in settlements around the enterprise. It also causes bronchial and broncho-associated diseases, inflammation of the mucous membranes of the eyes and other diseases in humans.

At present, much attention is paid to environmental safety in the republic. Various dust collectors are used to remove waste from production facilities and their emissions [16-22].

The main feature of dust is that dust is a small piece of solid matter dispersed in the air.

Dust can be of two types: organic and mineral. Cotton dust is mainly divided into 3 fractions:

1. Mineral dust with a size of 3-25 µm;
2. Organic dust 0.3-1 µm in size (cotton leaf seeds, leaf fragments);
3. Cotton fibers a few 10 µm long.

The smaller the dust, the more dangerous it is and the more harm it does to the human respiratory system.

Cotton dust contains up to 10% silicon dioxide (SiO_2). Based on this, the permissible concentration of suspended dust in the air is up to 4 mg/m^3.

The dust is divided into 3 types according to composition and form.

1. Small particles close in shape to a sphere (sand or soil dust).
2. Short two-dimensional powders (fragments of leaves and flowers of cotton).
3. Long thin, volatile filamentous powders (fibrous or purulent).

During the primary processing of cotton, the dust contains many mineral particles. In the later stages of cotton processing, mineral dust decreases and organic dust increases, i.e. organic dust increases as a result of the ingress of fiber, cottonseed or granules into a piece of equipment operating at high speed.

The dusty air of cotton-cleaning plants is cleaned mainly with the help of centrifugal dust collectors. The composition of dusty air released at all stages of the technological process of primary processing of cotton (reception, cleaning and storage, drying-cleaning, cleaning, linteration, pressing, etc.) depends on the efficiency of its cleaning. At the initial stages, a lot of dust is released, and in the later stages, the dust concentration decreases and can reach up to 10 g per 1 m^3 of air [23-29].

Of course, it is important to know the trajectory of dust particles in dust collectors and the path of passage depending on their mass.

Taking into account the above, the purpose of this study is to theoretically study the effect of fractions in improving the cleaning efficiency of dust collectors.

In fulfilling this goal, the following tasks were identified.

1. Theoretical study of the trajectory of the dust fractions coming out of the cotton ginning plant in the dust holder based on the Lagrange equations of type 2;
2. To study the dependence of the radial speed and angular speed of the dust particles entering the dust holder on the movement trajectory of the particle;
3. Theoretical study of the time it takes for a particle to reach the wall of the dust chamber;

4. To study the number of rotations of the trajectory of the moving particle along the wall according to the height of the camera.

Experimental

Materials and Methods

Considering the design of the dust collectors, let us analyze the movement of dust particles in the working chamber. Based on the diagram shown in Fig. 1, we will show the forces acting on it. To describe the trajectory of motion in space, we express the forces acting on the *x, y, z* axes.

At all stages of the primary processing of cotton, a large amount of dust is released, which pollutes the dust production facilities and atmospheric air, worsens the working conditions of workers and employees, and can lead to occupational diseases, especially silicosis. The issue of dedusting cotton-cleaning enterprises is of paramount importance in connection with the increase in contamination of machine-picked cotton. In connection with the ever-increasing introduction of cotton harvesting in the cotton ginning industry, it is necessary to take immediate measures not only to improve the technological process of receiving, storing and preparing cotton for processing, drying, cleaning and processing, but also to improve dust removal and air purification systems.

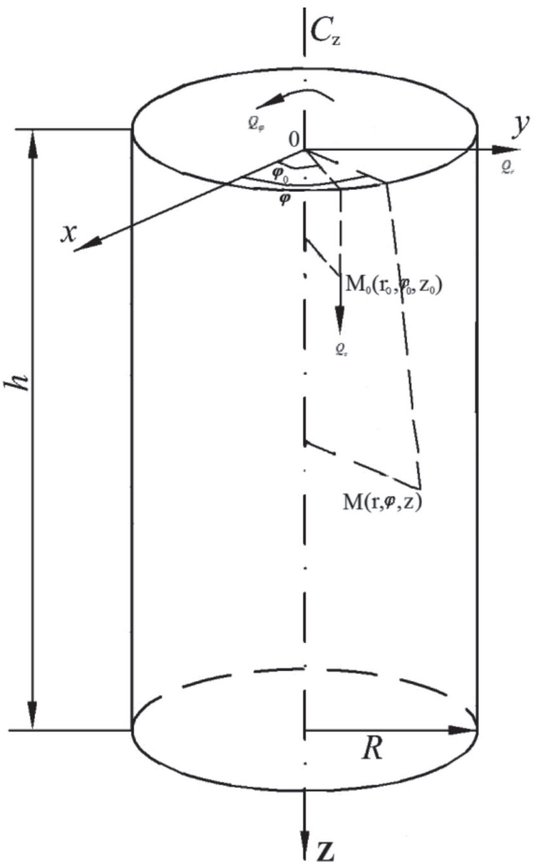

Fig. 1. Forces acting on the dust collector.

Later, due to the fact that we switch to machine collection, the contamination and moisture content of cotton increases. These factors increase the activity of a normal fungus that lives in the harvested cotton mass, these fungi turn into dust during cotton processing at enterprises and increase its harmfulness. That is why it is important to study the trajectory and parameters of particle entry into the dust collector and to study the dependence of the air flow rate in order for the dust collector to work smoothly. The more the air flow entering the dust collector moves along the wall of the dust collector, the more dust particles are separated in it, which also depends on the speed of the incoming air flow. To do this, we direct the *OZ* axis vertically from top to bottom, determining the position of the particle in the cylindrical coordinate system [2].

$$x = r \cdot cos\varphi, \quad y = r \cdot sin\,\varphi, \quad z = z \tag{1}$$

We take the coordinates *r, φ, z* as generalized coordinates and use the type 2 Lagrange equation, that is to say

$$\begin{aligned} \frac{d}{dz}\left(\frac{\partial T}{\partial \dot{r}}\right) - \frac{\partial T}{\partial r} &= Q_r \\ \frac{d}{dz}\left(\frac{\partial T}{\partial \dot{\varphi}}\right) - \frac{\partial T}{\partial \varphi} &= Q_\varphi \\ \frac{d}{dz}\left(\frac{\partial T}{\partial \dot{z}}\right) - \frac{\partial T}{\partial z} &= Q_z \end{aligned} \tag{2}$$

here: *T* – kinetic energy of the particle, equal to

$$T = \frac{1}{2} m\left(\dot{r}^2 + r\dot{\varphi}^2 + \dot{z}^2\right) \tag{3}$$

Qr, Qφ, Qz – generalized forces:

When determining the generalized forces, we determine the air resistance force acting on the particle as follows:

$$\vec{F} = F_r \cdot \vec{e}_r + F_\varphi \cdot \vec{e}_\varphi + F_z \cdot \vec{e}_z \tag{4}$$

here: F_r, F_φ, F_z – generating forces on the axes. $\vec{e}_r$, $\vec{e}_\varphi$, $\vec{e}_z$ - unit vectors.

If α, β, γ are support cosines, then we have the following:

$$F_r = |F| \cdot cos\alpha\,, \; F_\varphi = |F| \cdot cos\beta\,, \; F_z = |F| \cdot cos\gamma \tag{5}$$

We say that the air resistance is proportional to the square of the particle velocity (projections υ_r, υ_φ, υ_z of the airflow velocity on the *r*, *φ*, and *z* axes).

In this case $\left|\vec{F}\right| = c \cdot \rho \cdot \frac{S_0}{2}\left[(\upsilon_r - \dot{r})^2 + (\upsilon_\varphi - r\dot{\varphi})^2 + (\upsilon_z - \dot{z})^2\right]$

here: *c*- coefficient, $c = 0.5$.

The components of the vector $\vec{F}$, directed along the coordinate axes, are calculated by the following formulas.

$$Q_r = F_r = \frac{c\rho\rho}{2} \cdot (\upsilon_r - \dot{r}) \cdot F_0$$
$$Q_\varphi = F_\varphi = \frac{c\rho\rho}{2} \cdot (\upsilon_\varphi - r\dot{\varphi}) \cdot F_0$$
$$Q_z = F_z = \frac{c\rho\rho}{2} \cdot (\upsilon_z - \dot{z}) \cdot F_0 \qquad (6)$$

here: $F_0 = \sqrt{(\upsilon_r - \dot{r})^2 + (\upsilon_\varphi - r\dot{\varphi})^2 + (\upsilon_z - \dot{z})^2}$

Substituting T from formula (3) and Q_r, Q_φ, Q_z from formulas (4), (5) into (2), we obtain the following system of equations for determining *r, φ, z*:

$$\ddot{r} = r \cdot \dot{\varphi}^2 + \frac{c \cdot S_0}{2 \cdot m} \cdot (\upsilon_r - \dot{r}) \cdot F_0$$
$$\ddot{\varphi} = -\frac{2\dot{r}\dot{\varphi}}{r} + \frac{c \cdot S_0}{2 \cdot m \cdot r^2} \cdot (\upsilon_\varphi - r \cdot \dot{\varphi}) \cdot F_0$$
$$\ddot{z} = \frac{c \cdot S_0}{2 \cdot m}(\upsilon_z - \dot{z}) \cdot F_0 + g \qquad (6)$$

The system of (6) equations $r = r_0$, $z = z_0$, $\varphi = 0$, $\dot{r} = 0$, $\dot{z} = 0$, $\dot{\varphi} = 0$ is solved numerically by the Runge-Kutte method under the initial conditions.

The solution of this system of equations is to determine the trajectory of dust particles reaching the cylinder wall.

Determining the arrival time of a dust particle on the cylinder surface at $t = t_0$, we obtain this differential equation without taking into account the *r* axis for the motion of a dust particle along the wall $t > t_0$:

$$\ddot{\varphi} = c \cdot \frac{\rho S_0}{2r^2 \cdot m}(\upsilon_\varphi - r\dot{\varphi}) \cdot F_1 - f \cdot \frac{\rho S_0}{2mr^2} \cdot \upsilon_r \cdot \frac{r\dot{\varphi}}{\sqrt{r^2\dot{\varphi}^2 + \dot{z}^2}}$$
$$\ddot{z} = c \cdot \frac{\rho S_0}{2 \cdot m}(\upsilon_z - \dot{z}) \cdot F_1 - f \cdot \frac{\rho S_0}{2 \cdot m} \cdot \upsilon_r \cdot \frac{\dot{z}}{\sqrt{r^2\dot{\varphi}^2 + \dot{z}^2}} \qquad (7)$$

here: $F_1 = \sqrt{(\upsilon_\varphi - r\dot{\varphi})^2 + (\upsilon_z - \dot{z})^2}$

We calculate the system of Equations (6) and (7) together using the "Maple-8" electronic calculation program, assuming that the total speed of the air flow entering the dust collector is $\upsilon_0 = \sqrt{\upsilon_z^2 + \upsilon_\varphi^2 + \upsilon_r^2}$ m/s, the axis of which enters the working part of the dust collector is perpendicular (i.e. to the inner side surface of the cylinder $\upsilon_0 = 0$ m/s), we determine how long, at what speed the air flow entering the dust collector touches the wall and how long it will stay in it.

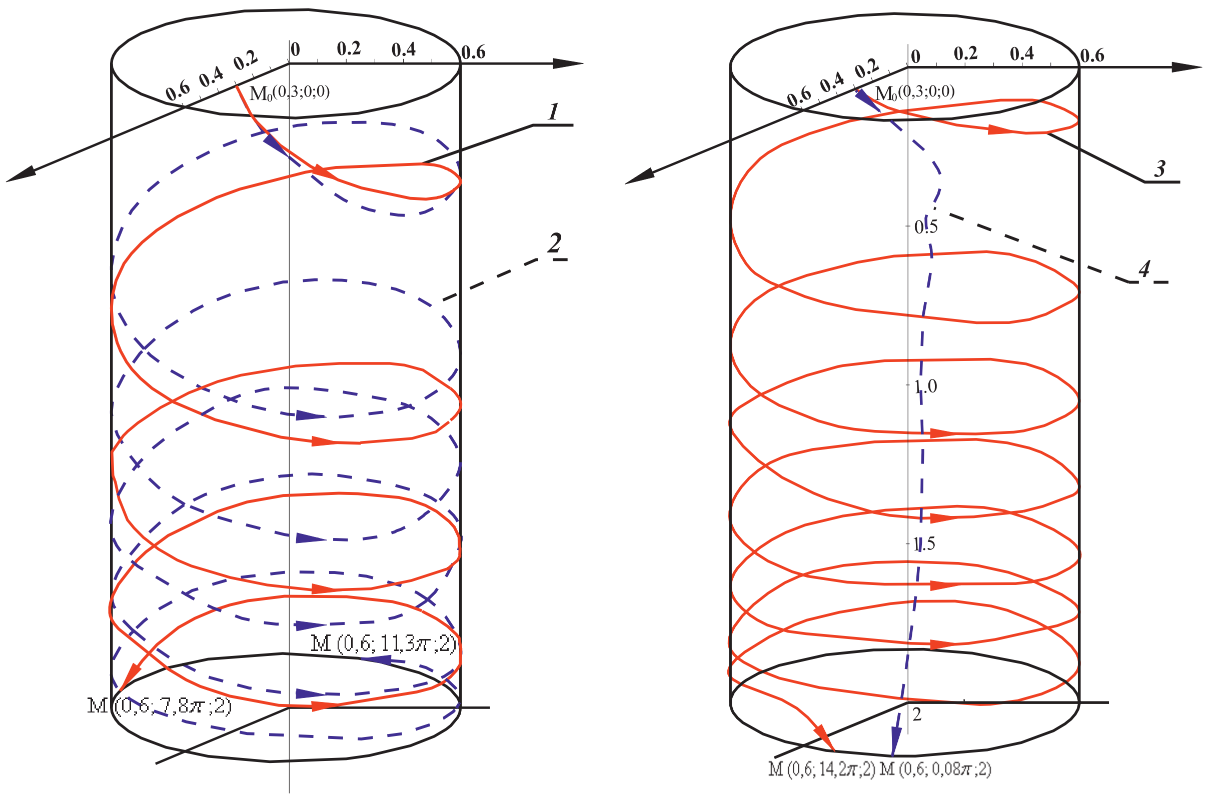

Fig. 2. At υ0 = 0, the trajectories of dust particles along the walls of the dust collector for various values of υr and υφ: 1) υr = 45 m/s and υφ = 45 m/s; 2) υr = 32 m/s and υφ = 55 m/s; 3) υr = 0 m/s and υφ = 64 m/s; 4) υr = 63,99 m/s and υφ = 1 m/s.

Table 1. Analysis of the velocity and exit coordinates of a particle falling into dust traps on a wall at velocities.

№	Particle velocity along the axis			Total particle speed ϑ_0, m/s	Time spent t, sek	The time the particle reaches the wall t_0, sek	Access coordinates	Output coordinates	Number of revolutions
	ϑ_r, m/s	ϑ_φ, m/s	ϑ_z, m/s						
1	45	45	0	64	1.898	0.14	0.3;0;0	0.6;7.8π;2	4
2	32	55	0	64	2	0.137	0.3;0;0	0.6; 11.3π;2	6
3	0	64	0	64	2	0.138	0.3;0;0	0.6; 14.2π;2	7
4	63.9	1	0	64	1.7	0.161	0.3;0;0	0.6; 0.03π;2	-

Results and Discussion

The calculation process was performed using "Maple-8" software. The program is designed to solve engineering problems. With its help, it is possible to perform accounting and book work in the departments of elementary mathematics and higher mathematics.

In this work, accounting and book work was performed using elementary mathematical formulas in the "Maple-8" program. In addition, accounting and book work was performed in "Maple-8" using the standard method for solving the differential equation. A special program was created using the "Maple-8" version to perform account book work.

Assuming that the coordinates and speed of the entry path of dust particles entering the workpiece are the same, the gap of the particle from the dust and the larger the path of impact against the wall, the higher the gap. We also monitor the operation time of the dust collector and select a rational mode. The results obtained are presented in Table 1.

Based on the results and equations obtained in Table 1, the spatial motion trajectory of the dust particles is shown in Figs 3-5.

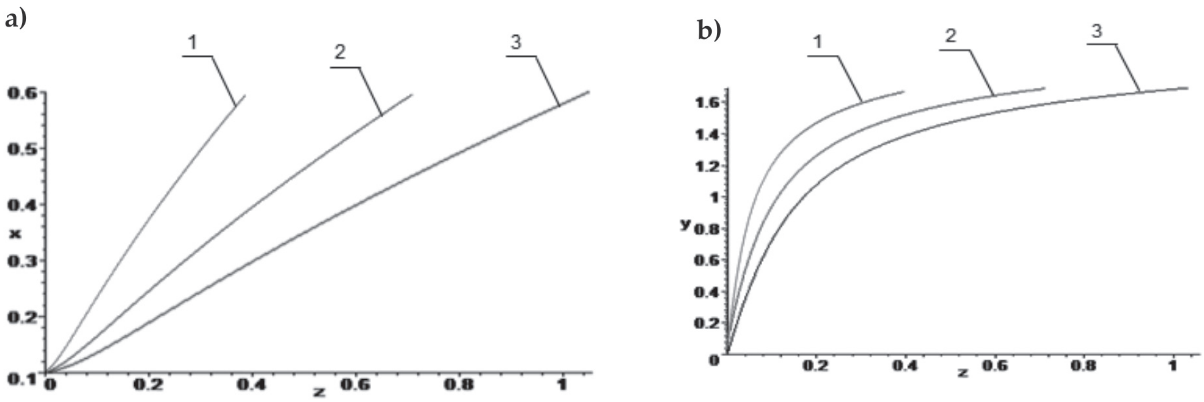

Fig. 3. The trajectory of the dust particles reaching the dust trap wall within a radius of 0.1 of the dust trap. a) along the xz axis; b) along the yz axis; 1- mass 0.001 kg; 2- mass 0.002 kg; 3- mass 0.003 kg.

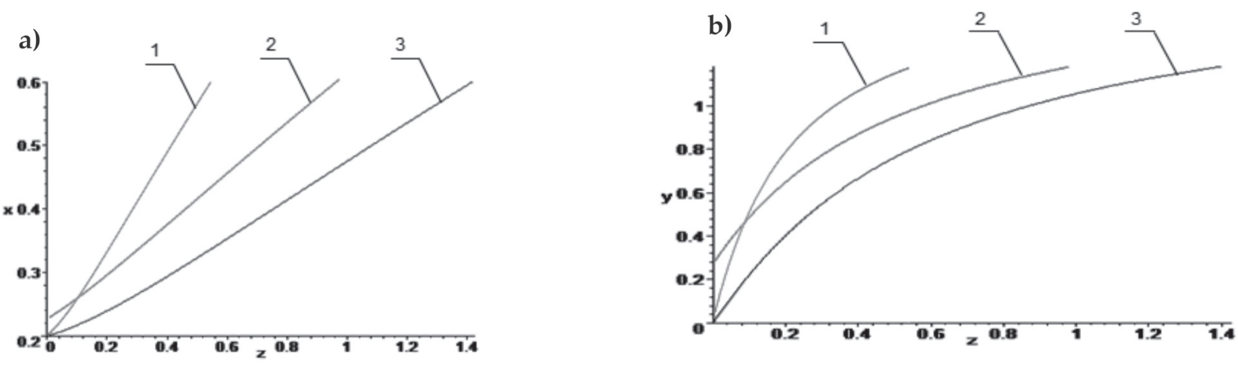

Fig. 4. The trajectory of the dust particles reaching the dust trap wall within a radius of 0.2 of the dust trap. a) along the xz axis; b) along the yz axis; 1- mass 0.001 kg; 2- mass 0.002 kg; 3- mass 0.003 kg.

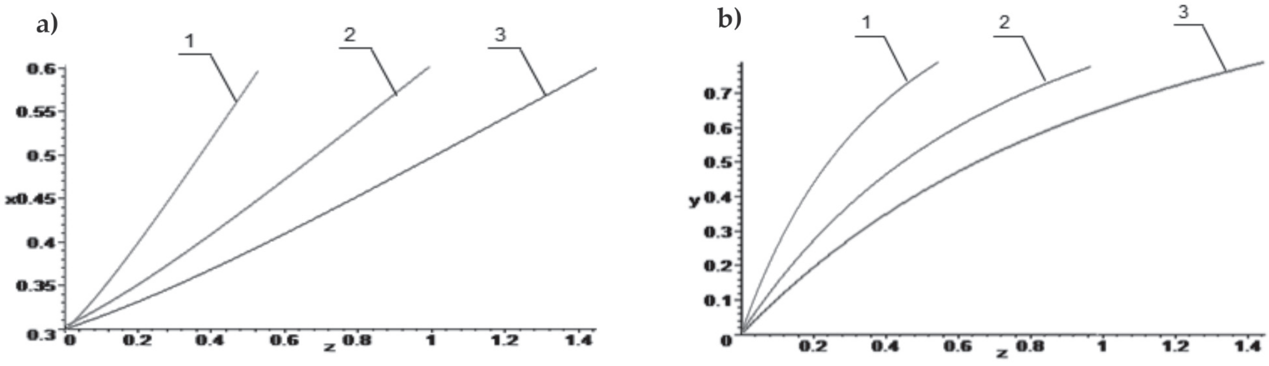

Fig. 5. The trajectory of the dust particles reaching the dust trap wall within a radius of 0.3 of the dust trap. a) along the xz axis; b) along the yz axis; 1- mass 0.001 kg; 2- mass 0.002 kg; 3- mass 0.003 kg.

In the "Maple-8" electronic calculation program, we take the results in tabular form and interpolate them to find the values of the argument and function in the form of vectors T, X, Y and Z, and then determine the spatial trajectory of the dust grain from the obtained values to Figs 6, 7.

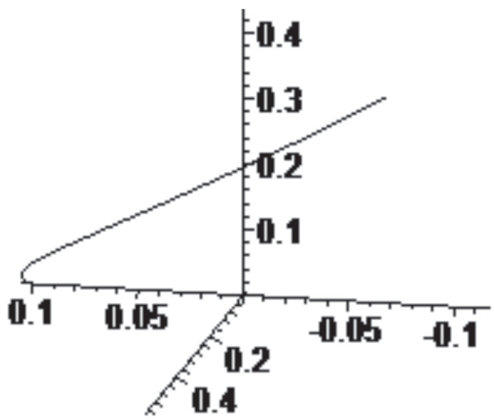

Fig. 6. Particle trajectory along the XYZ space plane. When the particle starts at a distance r = 0.1 m from the plane If the particle mass is m = 0.002 kg.

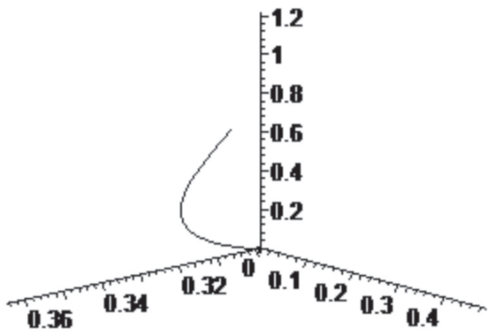

Fig. 7. Particle trajectory along the XYZ space plane. When the particle starts at a distance R = 0.3 m from the plane If the particle mass is m = 0.002 kg.

The obtained results show that the dust concentration coming out of the dust traps is below the standards. In order to prevent this and bring the concentration of dust coming out of the dust collector closer to the norm and reduce the amount of dust, research was conducted on the SS-6 dust collectors located at the cotton ginning enterprise "Korasuv" located in the Tashkent region of the Republic of Uzbekistan.

Conclusions

In conclusion, the properties of dust were studied and it was found that they mainly consist of 3 fractions.

– The theories of separation of these fractions in dust collectors were studied, particle movement trajectories were developed on the basis of type 2 Lagrange equations for their capture;
– recommendations were made;
– and the trajectories of particles inside the dust collector were determined based on the "Maple-8" calculation program.

When the total speed of the air stream perpendicular to the working part is $\upsilon_0 = 64$ m/s, the radial speed is $\upsilon_r = 0$ m/s, the angular speed of the particle is equal to $\upsilon_\varphi = 64$ m/s, and the starting point is M (0.3;0;0) It was proved in theoretical studies that a particle on a trajectory reaches the walls of the chamber for 0.138 seconds. It moves along the wall for 1.862 seconds and then falls to the bottom of the dust holder. During this movement, the particle rotates 7 times, and due to friction with the wall of the dust holder, the cleaning efficiency increases.

Acknowledgments

We express our gratitude to the Jizzakh Polytechnic Institute and M. Auezov South Kazakhstan University for the opportunity to conduct research.

Conflict of Interest

The authors declare no conflict of interest.

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