Dust flow motions in dust collection equipment, droplet trajectories and dynamics based on the dust collection chamber's technical characteristics

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Abstract. In the article, the object of research is the mode of operation of the existing and created at the cotton cleaning enterprise dust collection equipment and the degree of change in the amount of dust in the air. The methods of research in which modern methods of determining the parameters and aerodynamics of dust collecting equipment, experiments to determine the degree of pollution of the dust flow and statistical data, the development of a mathematical model of the dust flow in the networks of dust collecting equipment, the trajectory of droplets and dynamics, based on the technical characteristics of dust and gas cleaning chamber are presented.

1. Introduction

Nowadays, much attention is paid to the introduction of innovative technologies and methods of science and technology in the practice of industrial production in the developed countries of the world. Among other things, the leading role in environmental protection is played by the design of harmful emissions treatment systems for new types of equipment, their improvement, effective application of new technologies and, due to this, ensuring the reduction of emissions into the atmosphere in the territory of industrial enterprises. In this regard, certain achievements have been made in the developed countries of the world, and special attention is paid to the development of new design solutions in industry, which have been improved in the design of equipment for dusty air purification and scientific substantiation of methods of engineering calculations, providing energy and resource saving equipment. their introduction into production and increase in efficiency.

In the leading research centers of the world much attention is paid to the design of aspiration systems and equipment for dust removal, improvement of technological processes, increasing the efficiency of dust collecting equipment [1]. In the process of dust removal from air, development of perspective, highly effective design solutions of filters for dry dust collectors, as well as scientific substantiation and improvement of design methods and engineering calculations in order to improve high cleaning properties, strength and heat resistance, which can withstand sharp pressure drops, is one of the most important tasks [2].

Decree of the President of the Republic of Uzbekistan dated 28.01.20221 No. 60 "On the strategy of development of New Uzbekistan for 2022-2026", PF-5863 of the President of the Republic of Uzbekistan dated October 30, 2019 - It is important to timely carry out activities aimed at preventing environmental problems harmful to the natural environment, gene pool and health of the population, established by the decree "On approval of the concept of environmental protection of the Republic of Uzbekistan for the period up to 2030" and other normative legal acts related to this activity.

Ensuring the implementation of the decree of the President of the Republic of Uzbekistan dated October 23, 2019 "On approval of the strategy of development of agriculture of the Republic of Uzbekistan for 2020-2030", gradual reduction of expenditures on the state order, including the introduction of market principles that ensure free competition in the cultivation of cotton raw material, harvesting and, in this direction, in order to increase the interest of farms and broadly attract investment in the agricultural sector, will be organized voluntary cooperative farmers' cooperatives Their main tasks are preparation, transportation, storage, processing and organization of marketing of produced products. A new mechanism of crediting cultivation and processing of cotton raw material will be introduced.

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Among the topical problems - acceleration of dust particles deposition processes, development of high-performance dust-collecting devices to prevent air pollution and rational use of energy resources in the overall set of problems of priority cotton harvesting and scientific and technological progress of other industries for the Republic of Uzbekistan in the future. timely implementation of these measures [3-4].

2. Methods

The scientific significance of the research results is explained by the decrease in the formation of fine cotton dust formed in the production processes at cotton cleaning enterprises, the improvement of methods of calculation of ventilation pipes, passing the dust flow, based on the mathematical model, the creation of constructive solutions of energy-saving dust-collecting equipment and their improvement. Practical significance of the research results is explained by the development of constructive technical solutions capturing dust in moisture, in the improvement and reliability of energy-saving dust-collecting equipment, as well as increasing the efficiency of dust-collecting equipment as a result of the use of recommended design solutions and elements in the design practice.

Dust stream, which has passed through various stages of technological process, consists of organic and mineral components, its particle sizes range from several microns to several millimeters. The ratios between them are constantly changing during the technological processes. At the beginning of the technological process of primary processing of raw cotton, dust consisting of many mineral fractions is emitted from the air. The dust emitted during cotton processing, fluff and fiber extraction consists of organic matter consisting of fiber particles, bark particles, leaves and other parts of cotton. [5]

Microscopic studies allowed us to determine the morphological characteristics of dust particles. The organic fraction of dust consists of fibers of different sizes. Their size is from 15÷45 microns. 45-55 mm, due to twisting they fly in the air for some time and remain in a suspended state. In cotton cleaning shops common fibrous wastes of size from 100 to 1000 μm are found. Mineral dust particles consist of very fine atmospheric dust. The size of mineral particles varies from a few microns to 1000 microns. Their shapes are very different: lamellar, round, lance-shaped, etc. During primary processing, transportation, drying, cleaning, purification, cleaning, cleaning, linting and processing of fibrous cotton waste, a large amount of dust is emitted into the territory of the enterprise and into the atmosphere. The generated dust mainly consists of three fractions: dirty particles - crushed pieces of absorbent cotton; fibrous and mineral particles; During the primary processing of cotton, mineral, organic and fibrous impurities are separated.

In order to determine the waste coming out of cotton ginning enterprise, the fractional composition of waste coming out of the technological processes of cotton ginning enterprise belonging to "Kamalak Invest textile" LLC, Pasdargom district, Samarkand region was studied. [6]

At first, dust collectors of CS-6 type were investigated and advantages and disadvantages of this equipment were studied. First of all, the dust entering the dust collector CS-6 from each technological process was separated into fractions and its components were analyzed. The obtained results are presented in Table 1.

3. Results and Discussion

Fractional composition of wastes of technological processes of cotton ginning enterprise by sections is shown in Table 1.

Table 1. Fractional composition of wastes of technological processes of cotton ginning enterprise by sections, %

Fractional composition	I	II	III	IV	V
Waste from the drying plant					
Mineral	48	48	47	46	44
Organic	31	32	33,5	35	37
Fibrous	21	20	19,5	19	19
Waste from cleaning plant					
Mineral	38	40	40	40	42
Organic	35	35	34	33	30
Fibrous	27	25	26	27	28
Waste from the cotton ginning plant					
Mineral	4	5	6	7	7
Organic	39	40	38	36	35
Fibrous	57	55	56	57	58

Dryer dustiness averaged between 400 and 600 mg/m^3 in the drying room and between 1,300 and 1,500 mg/m3 in incomplete batches. Experimentally, it was found that dust levels differed depending on the cotton ginners and their

composition. Based on this, it showed that mineral waste is present up to 44-48%, organic waste up to 31-37% and fiber waste up to 19-20%. The drying agent used to dedust the drying plant is dedusted at a volume of 6 m3/s through a 550 mm diameter duct specially installed in the dryer shaft [7-8;].
A strong source of dust in a cotton ginning plant is fiber dust from the cleaning plant, dust from the air transport system and dust from the recycling air. This dust source mainly contains fiber debris as well as fine dirt [9].
The dust emitted in the fiber department, building air, and dust particle transport air is virtually free of mineral dust particles. The dust particles consist of fibrous particles from 5-6 mm to 0.5-0.25 mm and seed husks. After each lint, the dust consists of fine fibrous particles and seed husks.
During air transportation of down to the condenser, dusty air contains a lot of fine fibrous fractions. It can be concluded that the amount of mineral waste coming out of the drying and cleaning processes ranges from 1800-2000 g/hour, and at the final processes of ginning and linting this amount is 150-250 g/hour. The analysis showed that the dust content is insignificantly composed of fibrous waste and mainly mineral and organic waste [10].
The liquid is atomized by nozzles or by the energy of the turbulent air flow. In the water spraying chambers of the nozzles, cleaning of course and fine dusts up to 15-5 microns in size is achieved.
The process of dust deposition on the surface of droplets is widely used in industry. Capillary water droplet jets (nozzle scrubbers) or turbulent deposition of dust jet by water droplets (Venturi scrubbers) are considered. Wet dust collectors with nozzles capture coarse and fine dispersed dust particles of 5-15 microns in size.
Creation and substantiation of the mathematical model of aerodynamic processes in the gas stream of the gas cleaning system, the motion of droplets in the air stream V. It is described by the equation of motion of particles of variable mass M. Meshchersky:

$$m \frac{d\vec{V}}{d\tau} = \sum_{i=1}^{k} \vec{P}_i ,$$

Here: Pi is the sum of all forces affecting the reduction of air flow rate, m is the time-varying mass of the droplet, k is the initial diameter of the droplet; p is the density of water; v is the velocity of the droplet, t is the time.

$$\vec{P}_c = \frac{1}{2} c_m \, f \, \rho_? (\vec{W} - \vec{V}) \left|\vec{W} - \vec{V}\right| ;$$

$$\vec{P}_в = \vec{g} \, m ,$$

Here: cm - aerodynamic drag coefficient of the drop; $F=\frac{\pi \delta^2}{4}$ - surface of the Midelev cross-section of the middle part of the particle (drop); g - air flow density; V, W - drop velocity and air flow rate, respectively, g - vector of free fall acceleration (Fig. 1).

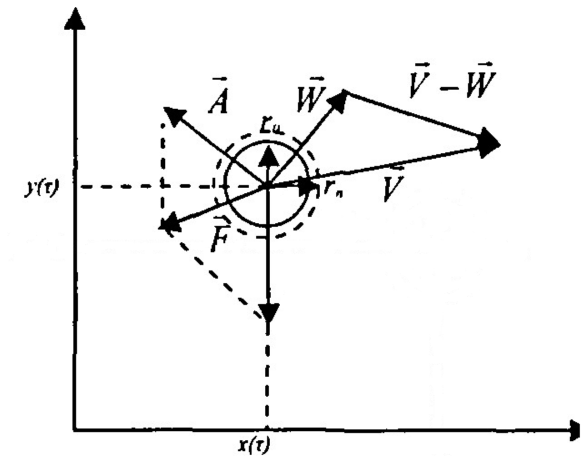

Fig. 1. Scheme for calculating the flow trajectory of a water droplet in a gas

Here: r_0 - drop radius; W, V - velocity vectors of dust, air and drops; A, P, F - aerodynamic drag, gravity and inertia forces; t-time;
The motion of a water drop in projections in a two-dimensional coordinate system is given by the equations:

$$\begin{cases} m\dfrac{dV_X}{d\tau} = \dfrac{c_m f\rho_z}{2}(W_X - V_X)\sqrt{(W_X - V_X)^2 + (W_Y - V_Y)^2} \\ m\dfrac{dV_Y}{d\tau} = \dfrac{c_m f\rho_z}{2}(W_Y - V_Y)\sqrt{(W_X - V_X)^2 + (W_Y - W_Y)^2} - mg, \end{cases}$$

Here: Vx, Vy - projections of drop velocity; Wx, Wy – projections of air flow; aerodynamic coefficient.
Drop resistance, which is determined by the value of Reynolds criterion:

Re< 1 (Stokes phase) cm = 24/Re;

D. N. Vyrubov's formula can be used for values of Re > 200 for spherical particles in a gas medium:

Nu = 0.24 [11-12]

Determination of pressure loss and local resistance coefficient in the flow pipe. Determine the pressure loss and the coefficient of resistance in the pipes through which the gas flow in the production shop of the cotton cleaning machine. At the boundary of transition from laminar flow to turbulent flow Re = 2320.

$$\lambda = 64/R_e = 64/2340 = 0{,}0273$$

$$\Delta p = \lambda \frac{L}{D}\frac{\rho v^2}{2} = 0{,}0273 * \frac{3{,}2}{0{,}45} * \frac{0{,}86 * 15{,}58^2}{2} = 23{,}6 \text{ Па}$$

Pressure loss in a pneumatic pipeline with constant cross-sectional area:

$$\Delta p_{пн} = \Delta p\ (1 + k\mu_{пр}) = 23{,}6\ (1 + 0{,}8 * 1{,}1) = 68{,}4 \text{ Па}$$

k - proportionality coefficient, 0.8
mpr - loading capacity of powder mixture

$$\mu_{пр} = G_т/G = 508{,}4/484{,}6 = 1{,}05$$

Gt - loading capacity of the mixture, G - loading capacity of air.
Pressure loss due to local resistance was determined as follows:

$$\Delta p = \xi\frac{\rho v^2}{2} = 0{,}86 * \frac{0{,}64 * 14{,}7^2}{2} = 59{,}5 \text{ Па}$$

Pressure loss at the air inlet

$$\Delta p = \xi\frac{\rho v^2}{2} = 1\frac{0{,}64 * 14{,}89^2}{2} = 70{,}9 \text{ Па}$$

$$\xi = \frac{\Delta p}{\rho v^2/2} = 1$$

Expansion pressure loss in expansion with change in cross section.

$$\Delta p = \eta\frac{\rho}{2}(v_1 - v_2) = 0{,}92\frac{0{,}86}{2}(14{,}9 - 3{,}64) = 4{,}5 \text{ Па}$$

Pressure loss in contraction with cross-sectional change

$$\Delta p = \eta_в\frac{\rho}{2}v_2\,(v_2 - v_1) = 0{,}94\frac{0{,}64}{2}14{,}89(14{,}89 - 3{,}41) = 51{,}4 \text{ Па}$$

Table 2. Results of analysis of heating, vibration and atmospheric products of Samarkand Kamalak Invest LLC, a cotton cleaning company

Source number and name	Name of ingredient (pollutant)	Quantity of waste before entering the dust collector	Quantity of waste at the outlet of the dust collector	Retention efficiency of the dust collector
Source #11 VZP-1200	Cotton dust	1,49 г/с	0,201 г/с	86,5 %
No.6 Newly installed equipment	Cotton dust	1,47 г/с	0,038 г/с	97,4 %

4. Conclusions

On the basis of the analysis of the results of theoretical and practical research on the retention of fiber waste and improving the efficiency of dust cleaning in the treatment of exhaust air at cotton ginning enterprises the following conclusions are made.

On the basis of analytical analyses carried out at cotton cleaning enterprises, the technology of dusty air cleaning and the working process of existing devices were analyzed, and the characteristics of dust flow and dust particles were studied in preventing the deposition of dust particles that occurred during the technological processes in the production shop of the cotton cleaning enterprise.

1. It is determined that the efficiency of dust stream particle capture in cyclones depends on cyclone diameter and dust particle size, when it is necessary to clean a high-speed dust mixture, its movement in a single cyclone exceeds the optimum. speed, and increasing the diameter of the device reduces the cleaning efficiency.
2. The characteristics of cotton dust coming out of each process of cotton ginning plants were studied, and the degree of pollution change in the process sequence was analyzed, as well as the amount of dust in dust collection equipment and networks before and after the cleaning process. was determined;
3. Compared to the dust collector of CS-6 type, the cleaning efficiency of the dust collector of VZP-1200 type is high, and the cleaning efficiency can be increased up to 95-98% by using a wet dust collector of a new design.

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