Swirling flow for dust capture

D. A. Badalova[1, 2*]

[1]Tashkent State Technical University, Tashkent, Uzbekistan
[2]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan

Abstract. An apparatus is proposed that operates on the principle of gas purification from dust in counter swirling flows. In order to select the optimal design of the apparatus for trapping cellulose acetate particles from the exhaust air, the granulometric composition of the entrained material was determined. The differential curve of size distribution of cellulose acetate particles is given. The paper presents the results of the use of apparatuses with counter swirling flows for capturing dust of cellulose acetates from the exhaust pipes of silo towers. The possibility of using this type of apparatus as an industrial vacuum cleaner is considered. A diagram of an apparatus with counter swirling flows is given, and the principle of operation of an apparatus with counter swirling flows and the conditions that ensure the safety of the apparatus are described.

1 Introduction

A large number of modern technological processes are associated with crushing, grinding and transportation of bulk materials. In this case, part of the materials inevitably passes into the aerosol state, forming dust, which is released into the atmosphere with process or ventilation gases [1].

Cellulose acetates obtained by a homogeneous method are white flakes. Cellulose acetate obtained by a heterogeneous method retains the shape of the original fiber. Several grades of cellulose acetates are produced in the industry: secondary acetates for the production of acetate fibers, for cellulose acetate etrol and non-combustible varnishes; partially hydrolyzed cellulose triacetate and heterogeneous triacetate for triacetate fiber and the manufacture of non-combustible film and photographic film [2, 3].

Storage and mixing of cellulose acetate in the process of fiber production is carried out in vertical silo-type towers [2, 3]. Cellulose acetate fed by a conveyor to the top of the towers, falling from a great height, forms a dust cloud, which, released through the hatch of the towers, pollutes the air of the working area, and dust deposited on sites, building structures and equipment creates a potential explosion and fire hazard in room. Currently, there are no dust collectors at acetate fiber enterprises.

Install a device for separating particles on the hatch for the exit of displaced air on the tower. Such an apparatus, operating on the principle of gas purification from dust in counter

*Corresponding author: iscmmstiai2022@gmail.com

swirling flows, was used by employees of the Tashkent State Technical University in a - chemical workshop.

2 Methods

Improvement and prospects for the development of the dust collector are associated with the possibility of the degree of purification of the outgoing gas, improving their aerodynamics and reducing harmfulness. As a result of the generalization of experimental data and the use of the fundamentals of the theory of aerodynamics , the following basic principles of the organization of the working process form the basis for the design of an effective dust collector with swirling flows: When choosing the optimal design of the apparatus for trapping cellulose acetate particles from the exhaust air, the granulometric composition of the entrained material was determined. The principles of sedimentation or retention of the suspended phase are used.

The correct determination of the influence of factors on the efficiency of dust collection is the most important task for the design of dust collectors with swirling flows, their selection and development of an engineering calculation method, as well as for the transition from laboratory to industrial installations (scale transition problems).

The study of the efficiency of capture was carried out according to the following method. The operating mode of the apparatus was set, the total flow rate and the ratio of the flow rates through the channels were set. The air flow rate was measured using a pneumatic tube in the outlet. Sampling was carried out through a NIIOGAZ sampling tube connected to an allonge containing an AFA-VP-20 filter. The duration of the experiments was recorded with a stopwatch and was 5 minutes in each mode. For each mode, 3 experiments were carried out.

The total load on the gas phase through the apparatus was $Q_{\text{мах}}$= 1000 m³/h, which corresponds to a velocity of 8.85 m/s. The decrease in the efficiency of capture with a decrease in the load on dusty air can be explained by a decrease in twist (i.e., the level of tangential velocity decreases, therefore, the centrifugal force acting on dust particles decreases).

2.1 Main part

Currently, several hundred different designs of devices for cleaning gases from dust are known. Despite their diversity, they are all instrumental designs that use a few basic principles of sedimentation or retention of the suspended phase.

Depending on the nature of the forces used in dust collectors to separate dust particles from the gas flow, they are divided into four main groups: dust settling chambers and cyclones, wet gas cleaning devices, porous filters, electric filters [5].

When choosing the optimal design of the apparatus for trapping cellulose acetate particles from the exhaust air, the granulometric composition of the entrained material was determined. From the differential distribution curve of cellulose acetate particles by size - (Fig. 1.) it can be seen that in the entrained material more than 70% (mass.) of fractions have a particle size of less than 45 mkm, with a significant part being fractions with a particle size of 10-20 mkm.

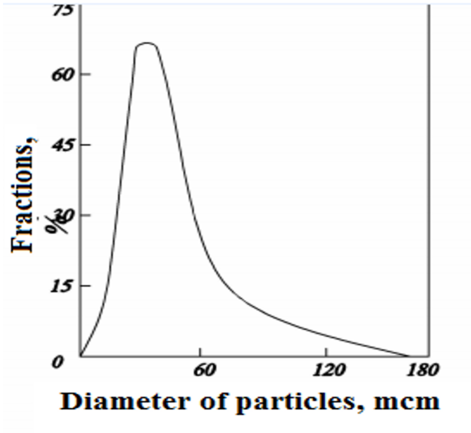

Fig. 1. Differential distribution curve of cellulose acetate particles by size.

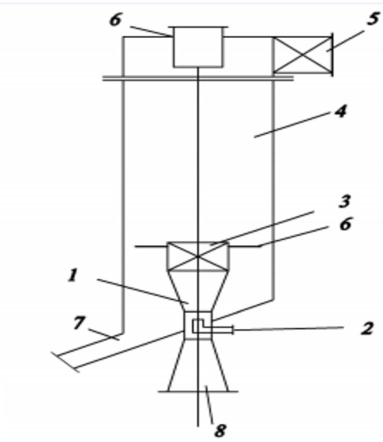

Fig. 2. Scheme of the apparatus with counter swirling flows: 1 - ejector device; 2 - tube for supplying compressed air; 3 - lower swirler ; 4 - cylindrical chamber; 5 - top swirler ; 6 - distribution washer; 7 - branch pipe for removing material; 8 - exhaust pipe

The apparatus is notable for its simple design, compactness, ease of use, high efficiency of trapping cellulose acetate particles (99.7% at air dust content from 3 to 25 g/m^3) and process continuity [5]. The main difference between vortex dust collectors and cyclones is the presence of an auxiliary swirling gas flow [5, 6].

In the apparatus of the nozzle type, the dusty gas flow is swirled by a vane swirler and moves upward, being exposed to the action of three jets of secondary gas flowing from tangentially located nozzles. Under the action of centrifugal forces, the particle is thrown to the periphery, and from there - into the spiral secondary gas flow excited by the jets, directing them down into the annular annulus. The secondary gas in the course of a spiral flow around the stream of purified gas gradually completely penetrates into it. The annular space around the inlet pipe is equipped with a retaining washer, which ensures the irreversible descent of dust into the hopper [5-7].

The principle of operation of the apparatus with counter swirling flows (Figure 2) is as follows. The air displaced from the tower, together with cellulose acetate particles, is sucked in by the ejector device 1 due to the supply of compressed air into the tube 2. Further, the gas flow through the lower screw swirler 3 enters chamber 4, forming an internal ascending swirling flow. Compressed air coming from the pipeline, passing through the upper tangential swirler 5, forms an external downward swirling flow directed towards the internal swirling flow. Due to the action of centrifugal force, the material is washed out of the internal flow into the external flow, rushes down and through the gap between the distribution washer 6 and the chamber body is discharged through the pipe into the container for the trapped dust. In this case, the purified air from the external swirling flow on the way from the swirler 5 to the distribution washer 6 passes into the internal flow and is removed into the room through the exhaust pipe 8. The device is grounded, which ensures the removal of static electricity.

Dust-laden air is diluted in the apparatus with clean air to a concentration much lower than the lower explosive limit of cellulose acetate dust. In addition, the absence of moving parts in the device eliminates the formation of a thermal pulse that contributes to the occurrence of an explosion. These conditions ensure the safety of the device. The pressure loss in the apparatus with a diameter of 80 and a height of 300 mm does not exceed 690 Pa [8-10].

The most important characteristic of any dust-collecting device is the efficiency of dust-collection. As is known, the overall efficiency of capturing the apparatus depends on the disperse composition of the dust.

The efficiency of trapping particles of cellulose acetate (in %) was determined by the formula

$$\eta = G_{yd} / G_{total} \cdot 100\% \quad (1)$$

where G_{yd} is the mass of the material caught in the apparatus, kg; G_{total} - the mass of the material fed into the apparatus, kg.

The efficiency of dust collection is influenced by a number of factors: the design of the apparatus, operating characteristics, physical and mechanical properties of dust (disperse composition, density, concentration in the flow, shape, stickiness, wettability, chemical composition, abrasiveness, etc.). The correct determination of the influence of all these factors is the most important task for the design of dust collectors, their selection and development of an engineering calculation method, as well as for the transition from laboratory to industrial installations (scale transition problems).

The operating mode of the device was set (total flow rate and ratio of flow rates through the channels). Using a pneumatic tube, the gas flow velocity in the exhaust pipe was measured.

Sampling was carried out through a NIIOGAZ sampling tube connected to an allonge containing an AFA-VP-20 filter.

The overall collection efficiency and material balance were checked by the weight of the initial dust and the dust collected in the dust collector bin.

The total load in the gas phase through the VZP apparatus was $Q_{\text{мах}}$= 1000 m³/h, which corresponds to a velocity of 8.85 m/s. The decrease in the efficiency of capture with a decrease in the load on dusty air can be explained by a decrease in twist (i.e., the level of tangential velocity decreases, therefore, the centrifugal force acting on dust particles decreases).

From Fig.3 it can be seen that the apparatus completely captures particles smaller than 10 microns in size, which are practically not captured by cyclone dust collectors.

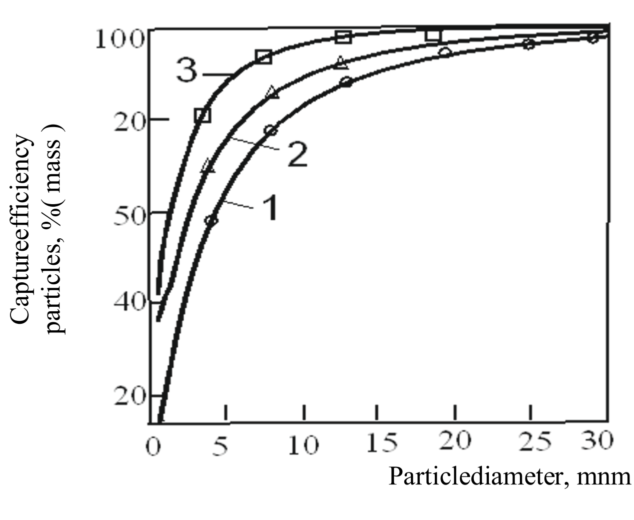

Fig. 3. Curvesthe efficiency of catching cellulose acetate particles by the apparatus with counter swirling flows in relation to the air flow in the upper swirler to the air flow in the lower swirl 0.75 (1), 1 (2) and 1.5 (3).

The ratio of air flow rates through the channels has a significant impact on the efficiency of dust collection (Figure 3.) As can be seen from the figure, with an increase in the ratio of costs, the efficiency of dust collection increases. The increase in dust collection efficiency with increasing flow ratio is explained by the influence of the secondary air flow on the tangential velocity component, which has a decisive influence on the centrifugal force that acts on dust particles. However, a further increase in the tangential component does not lead to an increase in the capture efficiency. So, if particles with a diameter of 4 μm are captured in a dust collector with swirling flows, then to create a mode for trapping particles with a diameter of 2 μm, it is necessary to increase the centrifugal force by eight times, respectively, the tangential component of the gas velocity by three times. In order for the tangential component of the gas velocity to increase by a factor of three, it is necessary to increase the total gas flow rate by a factor of three. The pressure loss in the apparatus in this case will increase tenfold. In addition, excessive dust collector overload [11,12]in the gas phase leads to an increase in the turbulence of the flow, which leads to re-entrainment and a decrease in the efficiency of dust collection.

Cellulose acetate storage and blending tower is not the only facility in chemical fiber plants that pollutes the atmosphere with particulate matter. Fibrous dust is formed when marking filter paper on paper unwinders. In addition, in textile shops, when rewinding the thread from bobbins to spools, blood fibers break, which settle on the equipment and the technical floor of the shop. The settled particles become oily, form aggregates and, getting on the rewound thread, contaminate it, lowering the grade of the products.

3 Results

The size distributions of cellulose acetate particles are presented in terms of differential particle distribution curve. It can be seen from the graph that in the entrained material more than 70% (wt.) of fractions have a particle size of less than 45 μm, with a significant part being fractions with a particle size of 10–20 μm. Also presented are curves of the efficiency of capturing particles of cellulose acetate with a device with counter swirling flows in relation to air consumption.

We have carried out industrial tests of the apparatus with counter swirling flows in the mode of capturing the fibrous dust of cellulose acetate. The efficiency of trapping cellulose fibers with a minimum diameter of 5 and a length of 15 μm averaged 99.3%. By introducing liquid into the apparatus, it is possible to increase the efficiency of catching fibrous dust up to 100%.

Collection of dust deposited on ceilings and metal structures can be carried out with an apparatus installed on a trolley together with an exhaust fan. In this case, the apparatus with counter swirling flows is used as an industrial vacuum cleaner.

The capture efficiency was determined by equation (1). The collection efficiency and material balance were checked by the weight of the initial dust and the dust captured in the dust collector.

In [11, 12], it seems that with an increase in dust content up to 18 g/m ^{3} there is a slight increase in the efficiency of capture, and then almost up to C = 0.5 kg/m ^{3} the value of η remains constant. Similar results, with slight deviations, were observed in the experiments.

4 Conclusions

In the vortex dust collector, no wear of the inner walls of the apparatus is observed, which is associated with the peculiarities of its air regime. The device is more compact than other dust collectors designed for dry cleaning of emissions.

Vortex dust collectors have the highest efficiency in capturing fine dust and their use is justified when capturing dust with a high content of fine fraction.

The use of improved designs of dust collectors will allow reducing energy costs for gas cleaning processes and increasing the efficiency of trapping solid particles.

Thus, an easy-to-manufacture apparatus with counter swirling flows can significantly reduce emissions into the atmosphere and return a significant amount of valuable material to production.

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