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Studies on the Hydrodynamics of the Combined Dust Collector on the Basis of Vortex Flows and Outer Filtering and the Development of the Effective Methods of Cleaning Gases from Solid Particles

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Running title: **Combined Apparatuses and New Efficient Methods of Cleaning Gases from Solid Particles**

Abstract

There has been developed a method for cleaning gas from solid particles and a laboratory model of combined dust collector on the basis of interacting vortex flows and filtration through one-piece filter element according to the principle of outer filtering has been made. Experimental studies on hydrodynamics of the combined dust collector have been carried out. The dependences of the hydraulic resistance of the combined dust collector and the efficiency of fine particles collection on operating and design parameters have been obtained. The results of the comparison of vortex apparatuses are given and a new method for gas cleaning in a vortex group dust collector is suggested.

Practical applications

Novelty of the developed combined method of gas cleaning from solid particulates consists in organizing two-stage purification process in a system of interacting vortex flows and external filtration through one-piece filter element with inner and outer side surfaces. Thus effective cleaning of gases from the coarse fraction with additional cleaning from fine particles by filtration at a low dust load on the material of the filter element is achieved in the centrifugal field interacting vortex flow.

Area of application of combined and group dust collectors - aspiration and pneumatic transport systems of food, chemical, medical and other industries

Key words: gas cleaning, combined dust collector, vortex flows, filtration, hydraulic resistance, collection efficiency, group vortex dust collector

Introduction

At present the development of effective combined dust collectors applied in aspiration and pneumatic transport systems of food industry enterprises and other branches is a matter of topical interest.

The advantage of combined dust collectors consists is reducing energy inputs for cleaning dust flows from suspended fine particles on combining several methods in a single apparatus. Thus, it becomes possible to reduce hydraulic resistance, specific quantity of metal and production floor space.

The article reports on new findings in the area of dust cleaning in combined dust collectors consisting in the development of a method for gas cleaning as well as working out a laboratory model of combined dust collector on the basis of interacting vortex flows and filtration through one-piece filter element according to the principle of outer filtering. Findings of the investigations in hydrodynamics are also presented. In particular, there were studied the dependences of the hydraulic resistance and the collection efficiency on operating and design parameters.

Development of combined dust collector on the basis of vortex flows and outer filtration

The authors have developed a new method for cleaning gases from solid particles and the construction of combined dust collector on the basis of vortex flows and external filtration (Fig. 1). Combination of centrifugal gas purification in two interacting vortex flows with additional cleaning by means of filtration in a developed apparatus ensures the rational use of energy of the gas flow during its redistribution between stages. In this case, more efficient use of the flow energy is achieved by performing the filtering stage in the form of one-piece cloth filter element with outer and inner surfaces arranged in concentric circles around the cylindrical chamber of centrifugal collection that is higher than the chamber.

It should be noted that first stage cleaning in a centrifugal field in the mode of interaction of peripheral and central flows that are supplied tangentially and move towards each other ensures increase of process efficiency as compared with cyclone cleaning. Thus, dust loading on a cloth filter element decreases.

A combined dust collector developed to implement a new method of cleaning gases from solid particles, operates as follows. Gas is supplied into a cylindrical chamber of centrifugal collection through peripheral and central inlet nozzles in a certain proportion. Peripheral vortex moves downward by external vortex, the central vortex moving upward by internal vortex. Their interaction ensures formation of upward cleaned from coarse fraction gas flow that is redistributed to the filter stage while saving twist energy. Because of the redistribution, the gas making a rotary translational movement is recleaned in the mode of external filtration by two ascending flows over the entire height of the outer and inner surfaces of one-piece filter element. Filtering occurs by the principle of outer filtration. This version of cloth filter element ensures an increase in filtration surface area up to 30% compared with the arrangement of a number of independent cloth filter sleeves on a concentric circle around the centrifugal collecting chamber.

There was made a laboratory model of combined dust collector on the basis of vortex flows and outer filtration with a diameter of the camera of centrifugal collection of 0.13 m, a height of 0.88 m and filtration surface area of the filter element of 2.58 m^2. Overall dimensions of combined dust collector are as follows: 1.66 m in height and 0.6 m in diameter.

Experimental studies of hydraulic resistance of combined dust collector

To study the hydrodynamics of the developed combined dust collector there was made an experimental unit. While carrying out the experiments total volumetric gas flow rate through the apparatus was changed in the range of Q=0.041÷0.083 m^3/s, and gas flow ratio of k=0÷1. Gas flow ratio is defined as the ratio of gas flow supplied through the peripheral inlet nozzle to the total gas flow through the apparatus.

Fig. 2 shows the dependences of the hydraulic resistance on the flow ratios in the stages and the combined dust collector as a whole at different relative heights of the filter element (h/H) at Q=0,069 m^3/s.

It has been found that with an increase in the relative height of the filter element filtration surface area increases, hydraulic resistance of the stages and of combined dust collector decreases in general and hence energy inputs for carrying out the process are reduced (Fig. 2). At the same time for the chamber of centrifugal collection and the combined dust collector there is a parabolic dependence of the hydraulic resistance on gas flow ratios (Fig. 2a-2b). Thus, when h/H=1 corresponding to the maximum surface of filtration area, and k=0.65 for the first stage ΔP reaches 1000 Pa, for the apparatus in general ΔP=1350 Pa.

Hydraulic resistance of the chamber of centrifugal collection and the combined dust collector in general is greatly influenced by flow ratios (Fig. 2a-2b). When gas is supplied in the same amount into peripheral and central nozzles the flow ratio will equal to k=0.5, which is characterized by minimum hydraulic resistance for the first stage ΔP=800 Pa. and for the apparatus in general ΔP=115. When gas flow supplied both into peripheral and central nozzles increases, hydraulic resistance rises.

Hydraulic resistance of the filtering stage has been found practically to be independent of gas flow ratios and when h/H increases it also decreases (Fig. 2c). When h/H=1 and k=0.65 ΔP=350 Pa.

Experimental studies of collection efficiency of the dust collector

Mass efficiency of collecting dust salt in the developed combined dust collector was studied (Fig. 3). The median diameter of dust salt particles is d_{50}=160mkm.

The first stage has been found to be characterized by an increase in the efficiency of dust salt collection to the value η_1=99.5% when gas flow ratio raises (Fig. 3a). However, excess of flow ratio value of k=0.8 results in collection efficiency decrease. It is caused by the entrainment increase out of separation area.

Thus, the collection efficiency of the combined dust collector equipped with one-piece filter element reaches η_0 = 99.99% (Fig. 3b).

Development of new methods and apparatuses for the efficient cleaning of gases from solid particles

Depending on the specificity of the manufacturing process, different requirements are imposed to the process equipment. For example, when collecting dust that is characterized by a significant content of coarse fraction it will be unreasonable to use high-performance combined dust collectors including filtration stage and filters as well and it will result in an increase in energy and material costs. To operate under these conditions apparatuses that ensure desired collection efficiency, but are characterized by lower hydraulic resistance can be used. The authors developed dust collectors on the basis of vortex flows, including: counterflow vortex dust collectors (CFDC) and direct-flow vortex dust collectors (DFDC).

A comparative analysis of the results of hydrodynamics studies of the developed CFDC and DFDC models with a diameter of separation chambers of 0.14 m in total gas flow rate through the apparatus Q=0.078 m^3/s, which corresponds to the planned speed of 5 m/s was made. It has been found that at gas flow ratio k=0.6, hydraulic resistance for DFDC was 1000 Pa, and for CFDC – 1250 Pa. Under these parameters, collection efficiency of skimmed milk powder with a median diameter d_{50}=19.2 μm in DFDC was η=91%, while trapping powdered sugar with d_{50}=16.7 μm in CFDC was η=72%.

The results of the comparative analysis of different types of vortex dust collectors make it possible to conclude that at equal modes of operation direct-flow vortex dust collector (DFDC) has a lower flow resistance than counterflow vortex dust collectors (CFDC). At the same time direct-flow vortex dust collector (DFDC) ensures sufficiently high collection efficiency of disperse materials.

To clean large amounts of dust gases the authors developed a novel method including interaction of peripheral and central flows of gas suspension supplied in the top part of the body, the flows swirling in the same direction and moving from the top to the bottom. Distinctive feature of the body is that the body consists of two cylindrical shells mounted without a gap in the line of their joining.

Conclusions

A method for high performance gas cleaning and construction of a dust collector on the basis of vortex flows and filtration through one-piece filter element has been developed. Experimental studies of hydraulic resistance and collection efficiency of the created combined dust collector have been made. The dependences of the hydraulic resistance and collection efficiency on the gas flow ratio and relative height of the filter element have been obtained. It has been found that when h/H=1 and k=0.65, ΔP of the first stage amounts to 1000 Pa, for the apparatus in general – ΔP=1350 Pa and filtration stages ΔP=350 Pa. At these values of operational and structural parameters collection efficiency of salt dust on the first stage η_1=99.5%, and the combined dust collector as a whole reaches to η_0=99.99%.

A new method of cleaning gases from solid particles in a high-performance direct-flow vortex group dust collector on the basis of vortex flows has been suggested.

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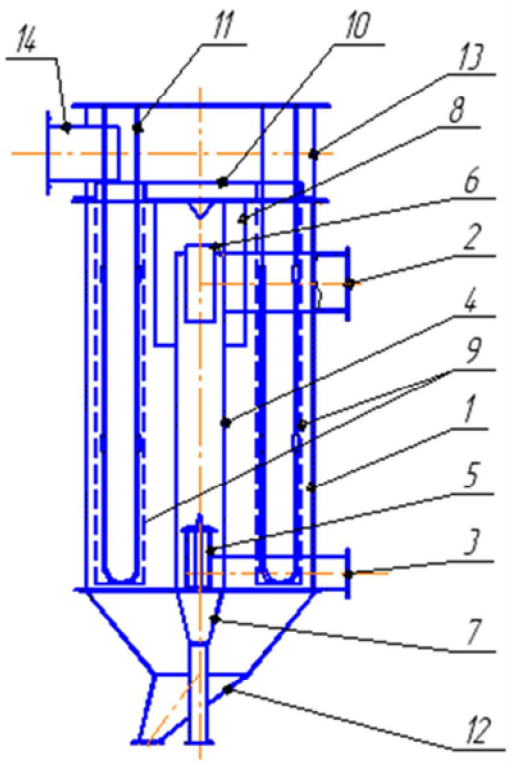
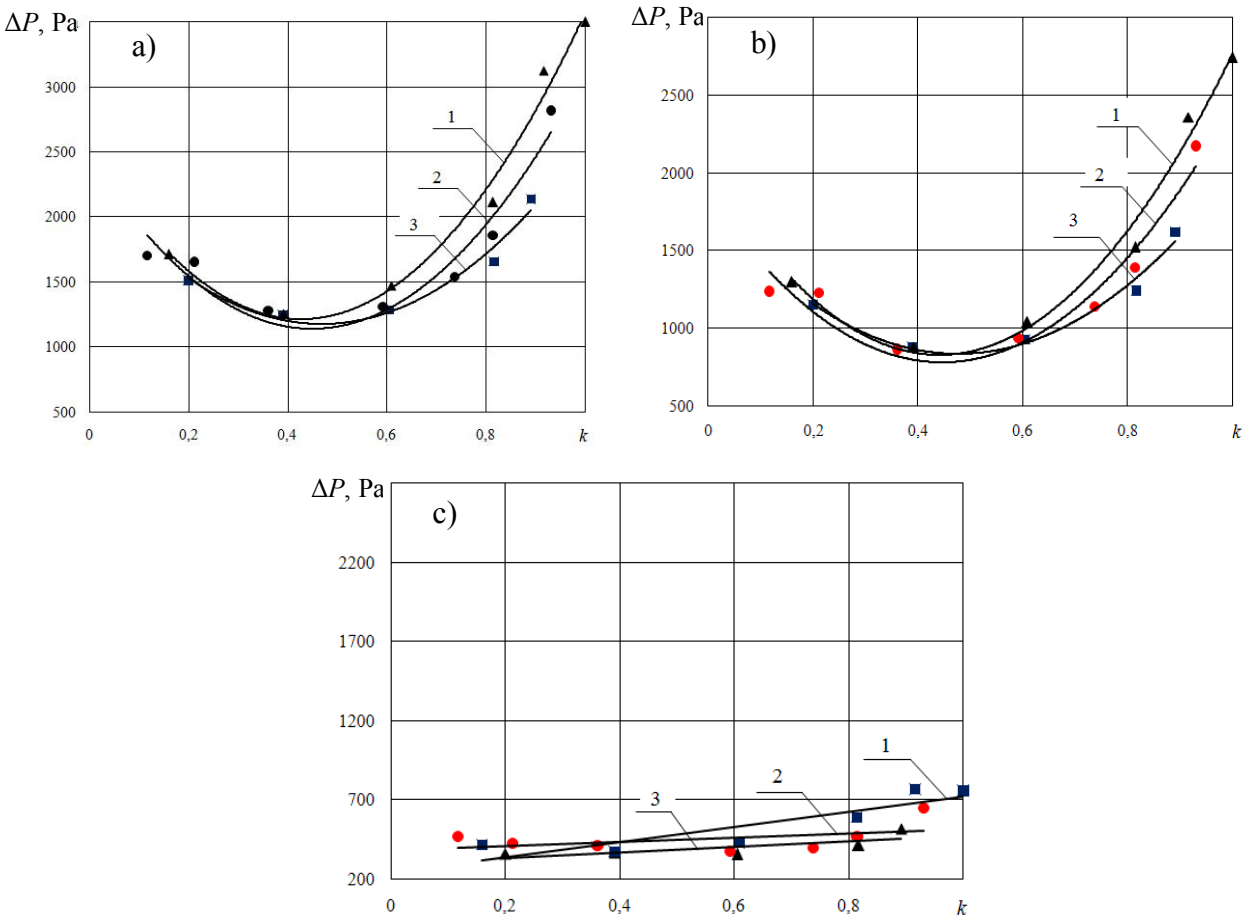


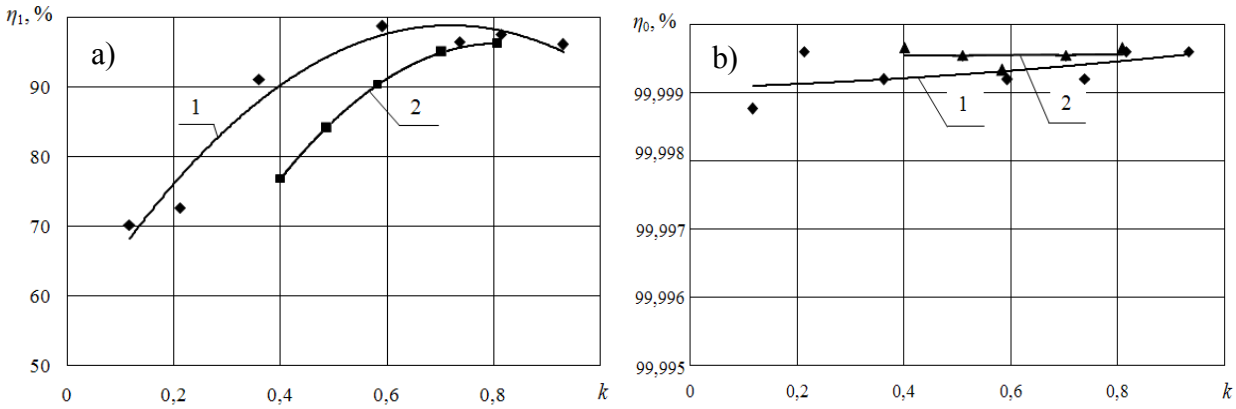
1 - cylindrical body; 2 - peripheral flow nozzle; 3 - central flow nozzle; 4 - cylindrical chamber of centrifugal collection; 5 - central flow swirler; 6 - exhaust pipe; 7 - coarse fraction bin; 8 - gas redistribution housing; 9 - filter element; 10 -grid; 11 - supporting frames; 12 – fine fraction bin; 13 - housing; 14 - nozzle of purified gas outflow

Figure 1. Scheme of a combined dust collector on the basis of vortex flows and outer filtration



1 – h/H=0,4; 2 – h/H=0,7; 3 – h/H=1

Figure 2. Dependences of the hydraulic resistance on the flow ratio for different relative heights of filter element at Q=0.069 m^3/s:
a) combined dust collector; b) centrifugal collection chamber; c) filter stage



1 – Q=0.069 m^3/s; 2 – Q=0.083 m^3/s

Figure 3. Dependences of the collection efficiency on the flow ratio at relative height of filter element h/H=0,7
a) centrifugal collection chamber; b) combined dust collector