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The problem of highly effective cleaning of air from dust

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Abstract. The article deals with the problem of providing high performance apparatuses for cleaning air from dust in various branches of industry in order to reduce hazardous emissions to the level conforming to sanitary-hygienic norms. The article describes new trends in the development of dust catching apparatuses based on the use of centrifugal-inertial forces, permitting to significantly improve the effectiveness of dust catching.

Key words: dust. catching, air cleaning, pollution, centrifugal, cyclone.

INTRODUCTION

Along with various natural phenomena (volcanic eruptions, forest fires, soil weathering and erosion, etc.) the human activities causing pollution of the atmosphere, connected with the use of natural resources and the development of industry, agriculture, construction and transport, play an ever growing role in the appearance of the problem and its solution. Due to the insufficient level of knowledge, inadequate technology or absence of comprehensive prognostic analysis these activities are accompanied by unwanted processes – emission into the atmosphere of the whole range of harmful by-products. Polluting the atmosphere, these by-products cause tremendous, often unjustified harm not only to the environment, but to humans as well.

The problem of prevention of atmosphere contamination has long ago crossed the borders of separate nations and even entire continents, and has acquired the status of the international problem and become common for practically all countries of the world. This has been determined by a number of reasons: solidarity of interests in the development of measures and means aiming at the reduction of levels or complete elimination of emissions of hazardous admixtures into the atmosphere, by the importance of collaboration and exchange of information on the development of methods and means of prevention of harmful consequences of atmosphere contamination and losses they create and, finally, by the fact, that the hazardous materials are carried over great distances regardless of the state borders.

Once it becomes evident, that the improvement of technological processes, establishment of sanitary-hygienic zones, increased height of smokestacks and other measures cannot reduce the level of pollution of atmospheric air to the maximum permissible concentration level, emissions must be purified to such a level, that in the end they do not exceed the norm of maximum permissible concentration.

The analysis of latest research works: at present the cleaning of contaminated air and gases is the main method of protection of air basin from pollution, applied in all cases when the use of active cleaning methods is still impossible or economically unfeasible. The task of industrial gas cleaning is the neutralization of the air basin from organized gas emissions and stationary pollution sources.

The cleaning of emissions is simplified considerably if emitted gases, for example stack gases, move along the gas ducts. In many cases, however, for example in operating mills, pickling installations, electroplating tanks, in dressing and cleaning castings, in plastic, glass-reinforced plastic, fabric-based laminate materials processing, etc. it is necessary to use special measures to avoid a direct emission of these materials into the atmosphere. In other cases, the admixtures not only become dangerous for the operators and adverse for the product quality, but become hard to catch.

For this reason, catching hazardous materials directly from the source of emission is the guarantee of not only improved hygienic conditions of labor at work places, but of high effectiveness of dust catching installations, which, as a rule, consist of the following elements:

– collecting device, which may consist of one or several dust collectors,
– grid of pipe-lines,
– fan, drawing off dust-laden or gas-contaminated air via pipe-lines to the dust-cleaning installation.

The systems of cleaning and decontamination of gas emissions can be conventionally divided into 2 large groups:

– group I – installations for cleaning from toxic gas admixtures (chemical cleaning),
– group II - installations for cleaning gas emissions from sprays (dust, smoke, droplets or fog).

MATERIALS AND METHODS

The greatest achievements in centrifugal catching of solid particles from a gas flow have been noted in the field of hardware design (engineering) and not in the field of scientific projects, which is explained on the one hand by the accumulation of long experience of operation of industrial installations and, on the other hand, by exceptional complexity of description of separate phenomena and characteristics of heterogeneous systems: rigid body – gas in centrifugal force field. For this reason, the theory of cyclone operation is still underdeveloped and does not provide an opportunity to calculate cyclones of various designs. For example, the problem of the most suitable shape of a cyclone till now is resolved only empirically or experimentally.

Different requirements are presented as to the level of final dust content in gas flows depending on physico-chemical properties of dust, technological parameters of dust-gas flows, especially with respect to fine toxic dust. For this reason, it is possible to find a range of decisions when solving the problem of design of centrifugal force apparatuses for separation of solid particles from gas flows. The analysis we have carried out showed a great number of various designs of centrifugal force apparatuses, whose design most often has not been supported by theoretical and experimental investigations of the structure of the formed flows and the process of separation of their particles.

We shall note, that the main effect on the efficiency of separation of solid dust particles in centrifugal force apparatuses is produced by improvements made on the apparatus body, whose purpose is, predominantly, to increase the centrifugal factor of separation or reduce the harmful effect of increased centrifugal factor of separation, or reduce the harmful effect of radial removal of dust.

A large number of various constructions of dust catchers for the same purpose, which do not have any clear specifications, stand in the way of selecting an appropriate system of cleaning in the process of design of dust catching devices, and absence of standardized dust cleaning equipment is an obstacle on the way to resolve the problem of organization of manufacture of such equipment.

To simplify the process of choosing the type of dust catchers for each specific case an attempt has been made to standardize, arrange in an order all known constructions of dust catchers, placing them by way of comparative testing in a small specific order by their efficiency, hydrodynamic resistance and specific quantity of metal per structure with equal power, air consumption in order to specify design of the apparatus with the best operating characteristics, which may become a prototype for the design of a new type of apparatus.

RESULTS AND DISCUSSION

For this purpose we have used the “Uniform techniques of comparative testing of dust catchers”, which include the item of preparation of experimental dust, determination of its parameters, means of contamination with dust of the air supplied to the dust catcher,

Table 1. Indices of dry dust catchers

Cyclone type	Degree of dust removal, %	Diameter, mm	Height, mm	Specific quantity of metal per structure, m^2	Surface area, m^2
LIOP	1.23	1.17	0.8	2.07	1.05
SIOP СІОП	1.05	1.62	0.7	1.82	0.92
VNDIOP	1.05	1.25	0.91	2.22	1.05
T-4/630	0.96	1.14	1.57	3.64	1.85
STN-11	1.00	1.00	1.00	1.96	1.00
STN -15	1.05	0.90	0.93	1.67	0.85
STN -15У	1.26	0.92	0.70	1.29	0.66
STN -24	1.35	0.75	0.72	1.09	0.55
Matroshka	1.62	1.43	0.92	3.67	1.86
UST -38	0.78	1.60	1.25	3.86	1.73
4B STSH	0.82	1.10	0.53	2.47	1.26

degree of diagglomeration of dust in case of artificial contamination of the air with dust, established as mandatory for conducting of bench tests of various types of dust catchers: air filters, dry-type cyclones, wet-type dust catchers, fabric filters, individual duct catching apparatuses.

Principal parameters dry-type dust catchers with similar power and air consumption, efficiency and pressure 1•103 Pa are shown in Table 1.

Efficiency is shown in the form of relation of dust removal from the given cyclone to dust removal from cyclone CN-11 (standard). Specific quantity of metal per structure is the value of the cyclone surface per 1000 m3/hr of the cleaned air.

To determine the place of domestic dust catchers we have provided specifications of the best foreign apparatuses in Table 2.

Modern gas-cleaning units for cleaning exhaust industrial gases to the degree, which meets the requirements of sanitary-hygienic norms, and installations, intended for cleaning of technological process, as a rule, cannot operate with high efficiency, because most of gas-cleaning units are rather complicated installations, consisting of a number of gas-cleaning apparatuses of various types, installed in several stages.

Table 2. Specifications of foreign apparatuses

Type of dust catcher	Productivity, m^3	Hydrodynamic resistance, Pa	Efficiency, %
D1-DIV Poland	800-100000	1350	92.2
TGL Germany	800-5760	1200	90
SGA Czechia	800-100000	1650	90.8
SHA England	800-100000	1730	91.2
TOSHIBA Japan	800-100000	850	94.1

Using our theory of the process of separation of heterogeneous systems by way of destruction of turbulent vortexes in dust catchers we can determine the minimal size of the particle moving under the influence of centrifugal force to the body wall upon its separation from the vortex and the maximal size of the vortex itself, thus determining dimensions of the apparatus, specifically the distance from the external to the internal wall of the body. Fine dust particles are under the influence of turbulent efficiency, which does not permit them to separate from the flow and they continue to move with the flow to the internal wall. The main task at this stage is freeing the particle from the influence of vortex, which is possible only in case of destruction of the latter. This can be achieved provided, that the internal wall of the apparatus is made in the form of shutter-type separator instead of one-piece wall.

Taking into consideration the mathematical model of the process of separation in centrifugal-inertial force dust catchers we have proposed a new group of apparatuses, whose operating principle is based on the combination of centrifugal, inertial forces and weight. The know-how of all groups is the presence in the apparatus body of the second cleaning stage – shutter-type separator, in which dust-and-gas flow is subjected to additional cleaning passing through the shutters.

The cleaning of air from dust in the apparatuses we have designed takes place as follows: dust-laden air comes in tangentially, predominantly to the upper part of the apparatus, where at first under the influence of centrifugal forces the flow is separated layer by layer: larger (by size and weight) particles of spray are deflected to the internal wall of the apparatus body and continue their circular motion along the wall, while fine particles move in circles along the internal single-piece outlet pipe for cleaned air. One half of revolution is sufficient for this process, which has been proved experimentally. At section 1 of the apparatus, the cleaning of the air from dust occurs in the way similar to cyclone operation. At section 2 of the apparatus, additionally to this process the secondary cleaning of the air from dust begins along the shutter separator placed coaxially to the apparatus body. Gas flow flows past the separator shutters and turns at the angle over 900 but less than 1800 and goes out to clean air outlet pipe through the openings between them. Fine dust particles which have not been separated from the flow by centrifugal forces also approach the separator, but owing to their inertia they lag behind gas and hit the separator shutters and, depending on their location on the shutters they are either repelled to the wall of the body and caught up by the dust flow moving there, or dragged again by gas going to the separator for additional cleaning, hit the shutters again and so on, till they finally get into dust flow moving along the walls of the apparatus body, which will transport them to dust outlet pipe. The number of collisions depends on the parameters of dust (dispersion composition, physico-chemical and morphometric indices), gas flow (velocities: when entering the apparatus, of movement in the apparatus body, of passage through the shutter separator) and design features of the shutters, determining the angle of attack (angle between the direction of movement of gas flow and area of each shutter) and clear opening area.

During many years we have been improving the design of these groups of apparatuses, upgrading their efficiency and structural elements in principle. We have most dramatically and effectively have improved the construction of the separator's shutters. Construction features of dust catchers and their elements are protected by the author's certificates and patents.

All experimental investigations were carried out using the standard experimental stand of the State University «Lviv Polytechnic» in accordance with the «Uniform manual» for comparative specifications of dust catchers using standard quartz dust with clearly specified median diameter.

As the result of experiments the following has been determined:

1) The effectiveness of dust catching increases with the increase of: total consumption of the air in the stand; median diameter of dust particles entering the dust catcher; hydrodynamic resistance.

2) The fraction effectiveness of dust catchers increases with the increase of median diameter of dust particles.

3) The hydrodynamic resistance of the dust catcher increases with the increase of consumption of the air in the stand.

Summing up the above, it is possible to claim that the effectiveness of dust catching will be increasing with:

– higher velocity of the dust particle before the separator,
– greater weight of the dust particle,
– greater density of the dust particle,
– smaller angle between the direction of movement of the flow and area of the shutter,
– lower velocity of the movement of cleaned air flow to the separator opening,
– greater clear opening area of the shutter separator,
– greater flexibility of dust particle,
– greater stability of the velocity of dust-air mixture along the separator, ensuring constant velocity of air passage through the separator.

CONCLUSIONS

Comparative investigations have proved, that the effectiveness of operation of the proposed dust catcher surpasses the effectiveness of operation of cyclone CN-11 (standard) by 15-17%, hydrodynamic resistance is reduced by 150-250 Pa, and dimensions by 1.5 times, which permits to make a statement of considerable reduction of power and metal consumption.

Further works in this field should be conducted towards an improvement of the design of shutter separator as the second stage of cleaning, towards optimization of the dimensions of dust catcher body and improvement of the processes of separation for further increase of effectiveness of dust catching, development of new energy saving technologies and protection of the environment.

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