

# EFFICIENCY OF DUST SEPARATING DEVICES IN VENTILATION EMISSION CLEANING SYSTEMS

**E O Sheremet, A S Seminenko, A B Gol'tsov, B F Podporinov**

Belgorod State Technological University named after V.G. Shoukhov, 46, Kostyukov St., Belgorod, 308012, Russia

E-mail: tgv.bel@gmail.com

**Abstract.** The article analyzes the main trends in the development of cyclone type inertial dust separators, as well as granular filters in both domestic and foreign practices. Designs of dust separating devices proposed by the Department of Heat and Gas Supply and Ventilation of BSTU named after V. G. Shoukhov are actively considered. The factors ensuring efficiency of dust separation, the calculated dependencies for determining efficiency of dust separation and hydraulic resistance of a combined granular filter for the capture of cement dust are considered.

## 1. Introduction

The increased volume of industrial production sets environmental protection as a top priority [1]. Pollution by industrial and ventilation emissions has a harmful effect on humans and animals, plants and soil, buildings and structures, reduces transparency of the atmosphere, degrades air environment quality, accelerates corrosion of metal products.

In these conditions, the problem of protecting the air basin of cities and enterprises from dust and gas emissions becomes increasingly important [1-5].

At the same time, an important task is the development of advanced dust-separating devices [4-8] which ensure high efficiency of emission purification and reduction of energy costs for purification.

## 2. Methodology

Domestic [1-3] and foreign [4-5] practices show that when dedusting industrial and ventilation emissions, dry inertial cyclone dust separators are widely used due to their simple manufacturing, installation and operation, rather high efficiency with decreasing hydraulic resistance.

The disadvantages of cyclones are: reduced dust separation efficiency of less than 5 microns, increased resistance of high-efficiency cyclones - 1200 ... 1800 Pa, blockage with sticking dusts and intensive wear when capturing highly abrasive dusts.

Recently studies have been conducted [6-8] aimed at increasing efficiency of cyclone devices, especially when capturing dust particles of medium dispersity (10 ... 30  $\mu\text{m}$ ) since the application of bag filters and electrostatic precipitators in this range entails unreasonably high costs.



### 3. Body of the study

Studies in the field of increasing effectiveness of dust separation devices are mainly focused on developing measures to improve the design of cyclone devices, and it is advisable to identify some of them.

Installation of an axial cylindrical insert in the dust outlet along with a reduction of cyclone hydraulic resistance allows reducing secondary drift of the dust, i. e. increase efficiency of cleaning in the device. This insert separates the hopper cavity from the body cavity and allows strengthening the descending flow and weakening radial flow in the lower part of the cyclone body, which reduces the secondary drift of the trapped dust from the hopper 3 ... 5 times and thereby reduces the dust emission in atmosphere 1.5 ... 2 times.

As a means of increasing efficiency and productivity of cyclones, the so-called combined supply of dusty flows at the entrance of the device and along its axis towards each other should be considered.

Tests have shown that the productivity of cyclones with a combined supply of dusty streams increases 1.4 ... 1.5 times with a hydraulic resistance equal to the resistance of normalized devices, and the secondary dust drift decreases 3 ... 4 times.

One way to improve the efficiency of cyclones is to use the ejection of the separated product from the cyclone hopper with a portion of the carrier gas stream. This principle is incorporated in the design of the cyclone dust concentrator of BSTU named after V.G. Shoukhov [9, 10]. Unlike the well-known design solutions, this device does not require additional thrust stimulator since gas extraction from the hopper is carried out due to the pressure drop in the hopper and the cyclone exhaust header. Cleaning of the separated dust flow is carried out in a filter located between the hopper body and the cyclone body. As shown by the conducted research, this solution allows reducing the dust emission from the device 2 times and reduce its hydraulic resistance by 15 ... 20%.

The scheme of a two-stage cyclone dust concentrator developed in BSTU named after V.G. Shoukhov is just a design of a direct flow cyclone with the removal of dust and gas concentrate with a counterflow cyclone located inside. The direct flow cyclone is the first stage, and the counterflow cyclone is the second stage. Hydraulic resistance of both stages is comparable to resistance of the cyclone TSN-11 at a higher cleaning efficiency.

A promising design of the cyclone with directional blades installed in the exhaust pipe is developed and studied at BSTU named after V.G. Shoukhov [6, 11]. The use of such cyclone provides valuable pressure loss without reducing cleaning efficiency.

The reduction of the dust-and-gas flow dustiness improves the cyclones' operation. For this purpose, BSTU named after V.G. Shoukhov developed a number of constructive solutions to improve the design of aspiration hoods [12, 13] providing reduction of dust coming from the dusting equipment and ultimately increasing efficiency of cyclones and other dust separators.

An important issue is the protection of cyclone bodies from abrasive wear. Abrasive wear of the flowing part of the cyclones is facilitated by the multi-turn rotation of the gas flow carrying the dispersed phase. Due to this rotation and the resulting centrifugal forces, solid abrasive particles are concentrated on the walls of the device resulting in erosion, i. e. abrasion of the walls up to the formation of through holes. The rate of such abrasion in individual cases can reach 12 mm per year.

The main measures to improve wear resistance of cyclones are currently the following: application of any wear-resistant coating to the wear surface; use of materials that are more resistant to wear under given conditions; change in the design of the cyclones leading to the reduction in wear due to the aerodynamic flow of gas. Quite often an effective operation of cyclones is hampered by deposition of highly sticky dusts on internal surfaces; one of the means of combating this may be the use of cyclones with a polished inner wall. An exceptionally effective means of combating sticking is to ensure elasticity of the walls of the cyclones, for example, using rubber which is periodically subjected to deformation for cleaning.

At certain production lines (for example, silicate brick production, cast iron sanitary casting, etc.) steam-dust ventilation exhausts are formed. During their dedusting, cyclones with a porous wall are used, in which the regeneration of the deposited dust is carried out by backwashing with compressed air. Chain suspension is also quite widely used; its free movement under the influence of the air flow

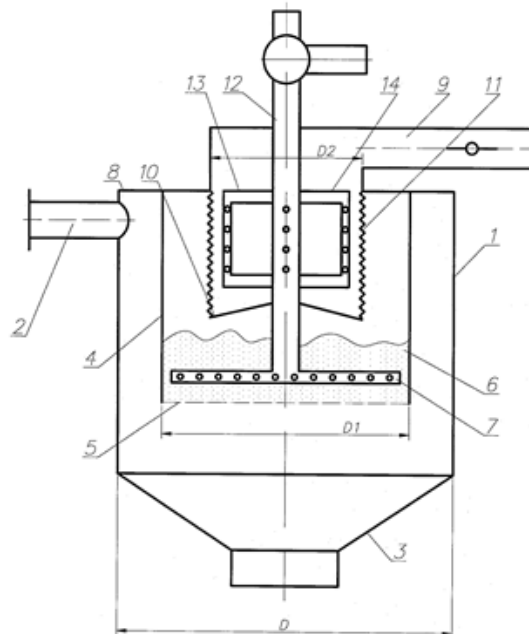
eliminates accumulation of dust on the walls of the cyclone. At the present time, the main method for dedusting steam and dust mixtures is thermal insulation method; it does not allow condensation of water vapor causing dust deposits.

Recently, filtering devices with bulk filter layers of granular bulk materials (granular filters) are increasingly used in the dust separation technique. Advantages of these devices are: low cost, compactness, availability of filtering materials, ability to work at very high temperatures and in aggressive environments, withstand large mechanical loads and sudden changes in temperature. These factors predetermine the ever-increasing use of granular filters for cleaning dust and gas emissions.

BSTU named after V.G. Shoukhov developed and implemented a promising design of a highly efficient combined granular filter [14], in which the surface area of the granular layer is smaller than the surface area of the filter cloth, and the diameters of the filter body, the body of the granular nozzle and the outlet perforated header are  $D_2 = (0.85 \dots 0.9) D_1$ ,  $D_1 = (0.9 \dots 0.85) D$ .

The dusty gas stream through tangential pipe header 2 enters the inner cavity of the cyclone element, where under the influence of centrifugal forces large dust particles emerge from the stream and settle in the conical part of dust bin 3. The dust released from the big particles is directed up through the openings of gas-permeable partition 5 and passes through filter granular layer 6 where it is cleaned, and then it passes through filter cloth 11 located on the perforated part of header 9 where the gas stream is finally cleaned from the smallest dust particles. The cleaned gas stream leaves the filter through pipe header 9.

Regeneration of the filter is carried out in the following sequence. The drive of the stirrer is switched on and at the same time compressed air is supplied through backwash header 12, then the air enters the hollow shaft of the stirrer. From there, through the holes, the compressed air enters hollow frame 14, which has holes on the vertical stands. When the frame is rotated, the air cleans the cloth clogged with small particles falling on the granular layer.



**Figure 1.** Combined granular filter: 1 - filter body; 2 - cyclone element with a tangential header for input of dusty gases, 3 - conical dust hopper; 4 - body for granular material, 5 - gas-permeable partition; 6 - filtering granular layer; 7 - stirrer made in the form of a hollow shaft with windows; 8 - cover; 9 - pipe header of purified gas; 10 - conical bottom; 11 - filter cloth; 12 - backwash header; 13 - hollow frame; 14 - nozzles for compressed air

Cleaning of the filtering granular layer during the filtration of dusty gases is carried out by means of rotary stirrer 7, in which compressed air is fed through backwash header 12. Particles of dust are released from the granular layer and settle in the dust bin under the influence of gravitational forces 3.

After experimental data processing, the authors [15] obtained the calculated dependences for determining efficiency of dust separation and hydraulic resistance of the combined granular filter during separation of cement dust.

The relative penetration of dust through a granular filter, as well as associated efficiency of cleaning dusty gases,  $\eta$  are functions of the criteria that determine the basic mechanisms for dust separation and some other dimensionless values discussed above.

The criterion dependence of the cement dust penetration through the bulk layer, which approximates the results of the experiment, is expressed as follows:

$$K = 1,43 \cdot 10^{-4} \text{Re}^{0,775} Stk^{-0,372} Ho^{-0,372} \left(\frac{d_k}{h}\right)^{-1,014} \left(\frac{Z_u}{\rho}\right)^{-0,451}. \quad (1)$$

Total efficiency of the combined dust separator is determined by the formula:

$$\eta = 1 - (1 - \eta_u)K(1 - \eta_m), \quad (2)$$

Total hydraulic resistance of the dust separator is equal to the sum of its stages resistances:

$$\Delta P = \Delta P_u + \Delta P_s + \Delta P_m, \quad (3)$$

and can vary between 100 and 3000 Pa depending on the duration of filtration.

The rational parameters of a combined granular filter are: height of the filtering layer in the filtering material is 100 ... 150 mm, average grain size of the granular nozzle is 3.0 ... 3.5 mm, dust content of the inlet air is 6 ... 7 g / m<sup>3</sup> and its filtration time is more than 40 min.

Depending on the filtration duration, the dust collection efficiency of the combined granular filter can vary from 97 to 99.97%.

#### 4. Conclusions

Until now, insufficient attention has been paid to the development of research on the study's theoretical foundations, principles of design, engineering calculation and development of highly efficient energy-saving devices and installations for cleaning venting emissions of dust-productive equipment.

The materials in the publication enable scientific and engineering workers, designers and postgraduates to:

- review theoretical fundamentals of the work and design features of the equipment used to clean up dust industrial ventilation emissions;
- study advantages and disadvantages, methods for assessing effectiveness and scope of different groups of dust collectors;
- master the methods of theoretical and experimental research of operation, modern engineering techniques in design and construction of dust-cleaning devices;
- develop scientifically based technical solutions to improve the design of advanced dust-collecting devices, ensure their efficiency and reduce energy costs for cleaning.

#### 5. Acknowledgments

The article was prepared within the development program of the Flagship Regional University on the basis of Belgorod State Technological University named after V.G. Shoukhov, using equipment of High Technology Center at BSTU named after V.G. Shoukhov. This work was supported by the Russian Foundation for Basic Research, agreement number RFFI № 16-08-00074a

#### References

- [1] Minko V A 2010 *Dedusting ventilation* (Belgorod: BSTU)
- [2] Logachev I N, Logachev K I 2005 *Aerodynamic bases of aspiration*. (Saint Petersburg: Khimizdat)

- [3] Uvarov V A, Podporinov B F, Seminenko A S 2013 *Methods and tools for cleaning of air emissions* (Belgorod: BSTU)
- [4] Huque S T, Donecker P, Rozentals J J and Benjamin C W 2010 *Transfer Chute Design Manual: For Conveyor Belt Systems*. (Conveyor Transfer Design Pty. Limited)
- [5] Howard Hartman L, Mutmanský J M, Ramani R V and Wang Y J 1997. *Mine Ventilation and Air Conditioning*. (Wiley-Interscience)
- [6] Chalov V A 2011 Theoretical justification for the design improvement of centrifugal dust collector. *Bulletin of BSTU named after V.G. Shukhov* **4**
- [7] Smirnov M E 2001 *Development of a method of calculation and the improvement of the design of the vertical direct-flow cyclone* (Yaroslavl)
- [8] Temnikova E J 2010 *Study of the efficiency of dust separation in the cyclone with embossed surfaces* (Kemerovo)
- [9] Minko V A, Ovsianikov J G, Logachev I N 2001 *Filecontentstore recirculation systems dedusting of local ventilation. 7th academic. reading RAASN: Modern problems in building materials* (Belgorod: BSTU)
- [10] Minko V A, Ovsianikov J G, Trishchenko S A, Kuleshov M I *Cyclone*. patent 1639768 USSR
- [11] Chalov V A, Kushchev L A, Shaptala V G *Cyclone*. patent 106147 RU
- [12] Feoktistov A J, Staroverov S V, Goltsov A B, Kireev V M 2013 Design of aspiration shelters for constricted conditions. *Chemical and Petroleum Engineering* **49** (3-4) 261-2645
- [13] Averkova O A, Logachev I N, Logachev K I, Khodakov I V 2014 Modeling detached flows at the inlet to round suction flues with annular screens. *Refractories and Industrial Ceramics* **5** (54) 425-429
- [14] Bogdanov V S, Sharapov R R, Kabanov S J *Granular filter*. patent 107484RU
- [15] Sharapov R R, Uvarov V A, Kabanov S J 2011 *Granular filters with stationary filtering layer* (Belgorod: BSTU)