To a Question of Energy Saving in Ventilation Systems of Industrial Buildings

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Abstract. In industrial buildings, a significant part of the energy costs are accounted for by the operation of systems that ensure the regulatory parameters of the air environment, both in the work area and in the territory of the enterprise. The article describes solutions aimed at reducing energy costs in the operation of dust collection systems in dust-free ventilation systems, as well as the results of an experimental evaluation of the effectiveness of these solutions. In addition, the proposed development allows to reduce the penetration of dust into the atmospheric air. The results of laboratory and natural studies confirming this are also given in the article. Reducing the concentration of dust in the air in the industrial site of the enterprise, in turn, allows not only to reduce energy costs for preparing air supplied to production facilities, but also to organize the return of valuable components to the production cycle. The described solutions refer to systems with inertial dust collectors.

1. Introduction
In the report "Ecological priorities for Russia" of the Analytical Center under the Russian Federation Government for 2017 year, as the most important for sustainable development of the country are named the reduction of negative environmental impact of cities in per capita terms, including special attention to air quality, and increasing energy efficiency of the economy [1].

2. Relevance
The solution of the above tasks also applies to ventilation systems of industrial buildings, since these systems are consumers of energy resources and their functional purpose is to ensure the standardized parameters (including the content of pollutants) of the air environment.

3. Scientific importance of the issue with a brief literature review
A lot of research has been devoted to the improvement of dust collection apparatus and installations for industrial ventilation systems, for example, [2-13], etc. However, it should be noted that mainly these studies are aimed at increasing the efficiency of dust collection. To a lesser extent, the authors consider the issues of reducing the aerodynamic drag of these devices and installations, as a parameter that largely determines the operating costs of ventilation systems.

In some papers [12, 15, 16], the authors give the results of the use of tangential flow untwisting devices in the dust collection systems with inertial systems. These devices, when installed at the outlet of the dust collectors, allow transferring the energy of the flow twist in the apparatus to the energy of axial movement. With the use of flow untwists, the aerodynamic resistance of the cyclone is reduced by about 15% and the vortex inertial apparatus with counter-twisted flows under various aerodynamic conditions of its operation - by 17.2-23.6% [12].
4. Problem statement
At the same time, the solution described above does not allow a reduction in the penetration of dust into the atmosphere [15, 16].

Simultaneous solution of tasks to reduce aerodynamic resistance and dust emissions in the atmosphere for the case of use in industrial exhaust ventilation systems can be achieved by organizing the suction of dust collectors from the hopper [17].

On the other hand, if different theoretical models can be used to evaluate the efficiency of inertial dust collectors [2-8], then a complex of experimental studies in both laboratory and industrial conditions is needed to evaluate their aerodynamic characteristics.

5. Theoretical part
To test the vortex dust collector with counter-swirling flows, a central composite rotatable plan was used [18] with the following determining factors:
- conditional speed in the middle section of the apparatus, referred to 1 m / s

\( \text{(1)} \)

- ratio of the supplied air flow rate through the lower input to the apparatus, to the total delivered for cleaning in the dust collector \( \text{(2)} \)
- ratio of the flow rate of air drawn from the hopper apparatus to the total supplied for cleaning to the dust collector \( \text{(3)} \)

6. Practical significance, proposals and results of implementation and experimental studies.
Presence of two inputs of a dust-air flow in the counter-twisted flows apparatus and organization of suction from the hopper make it possible to diversify the layout of the dust collection unit. Such installations have been proposed for enterprises of various industries [9, 10] and have successfully passed tests in the production of construction claydite [12, 19], lime [20], aerated concrete [9, 21], etc.

Some results of the experimental estimation of aerodynamic characteristics and dust penetration for the counter-twisted flows apparatus with suction from the hopper in the ventilation systems of industrial buildings are presented in Table 1 and on Fig. 1.

| Operating modes of the device | Magnitude of the aerodynamic resistance of the apparatus with counter-twisted flows, [kPa] | \( \Delta(\Delta P) \), [%] |
|-----------------------------|---------------------------------|-------------------|
|                            | without suction | with suction      |                        |
| \( \bar{v}_c \) \( L_{bot} \) \( L_{suc} \) | | | |
| 3.3 \( 0.1 \) \( 0 \) | 0.9 | 0.48 | - 46.7 |
| 3.3 \( 0.1 \) \( 0.1 \) | | | |
| 5.3 \( 0.1 \) \( 0 \) | 1.50 | | |
| 5.3 \( 0.1 \) \( 0.1 \) | | | |
| 4.3 \( 0.2 \) \( 0 \) | 0.92 | 1.32 | - 12 |
| 4.3 \( 0.2 \) \( 0.2 \) | | | |
| 3.3 \( 0.3 \) \( 0 \) | 0.73 | 0.69 | - 25 |
| 3.3 \( 0.3 \) \( 0.3 \) | | | |
| 5.3 \( 0.3 \) \( 0 \) | 1.08 | 0.44 | - 39.7 |
| 5.3 \( 0.3 \) \( 0.3 \) | | | |

The received results testify that the organization of suction from the bunker of the counter-twisted flows apparatus allows reducing its aerodynamic resistance. At the same time, the characteristics of
the dust fans installed in the dust collecting ventilation system show that when the pressure loss, for example, by 13%, is reduced, the installation power of the fan is reduced by about 22%.

**Figure 1.** Change in the aerodynamic resistance of the counter-twisted flows apparatus with suction from the hopper depending on the proportion of the flow delivered to the lower input \( \bar{L}_{bot} \) at: a) \( \bar{L}_{suc} = 0.1 \); b) \( \bar{L}_{suc} = 0.2 \); c) \( \bar{L}_{suc} = 0.3 \)

In addition, this solution reduces the penetration of dust into the atmospheric air, as evidenced by the experimental data shown in Table 2.

In turn, the reduction of dust penetration into the atmosphere can reduce the concentration of dust at the level of air intake openings and open gates (Table 3) and, therefore, reduce the energy costs for processing air entering the production facilities.

**Table 2.** Comparison of the efficiency of the counter-twisted flows apparatus without suction and with suction from the hopper

| Operating modes of the device | Value of a breakthrough for a counter-twisted flows apparatus, \( \varepsilon \) with suction | \( \Delta \varepsilon \) [%] |
|-----------------------------|----------------------------------------|------------------|
| \( \bar{v}_c \) | \( \bar{L}_{bot} \) | \( \bar{L}_{suc} \) | without suction | with suction |                      |
| 3.3 | 0.1 | 0 | 0.0501 | 0.0442 | - 11.8 |
| 3.3 | 0.1 | 0.1 | 0.0418 | 0.0359 | - 14.1 |
| 5.3 | 0.1 | 0 | 0.0378 | 0.0289 | - 23.5 |
| 4.3 | 0.2 | 0.1 | 0.0456 | 0.0368 | - 19.2 |
| 3.3 | 0.3 | 0 | 0.0376 | 0.0283 | - 24.7 |
| 5.3 | 0.3 | 0 | 0.0376 | 0.0283 | - 24.7 |
| 5.3 | 0.3 | 0.3 | 0.0376 | 0.0283 | - 24.7 |
Table 3.

| Dust cleaning apparatus                              | Concentration of dust in ambient air, [mg / m³] |
|------------------------------------------------------|-----------------------------------------------|
|                                                      | at the level of air intake                      |
|                                                      | at the level of windows                         |
|                                                      | at the level of mid-gate                        |
| Cyclone C-950                                        | 2.6                                            |
|                                                      | 2.03                                           |
|                                                      | 2.96                                           |
| Apparatus with counter-twisted flows with suction from the hopper | 0.94                                           |
|                                                      | 0.7                                            |
|                                                      | 0.88                                           |

7. Summary

1. The results of laboratory studies and pilot-industrial tests confirmed the practical feasibility of organizing suction from the hopper of inertial dust collectors (including vortex inertial dust collectors with counter-swirling flows).

2. It has been experimentally established that the proposed solution for vortex inertial dust collectors with counter-swirling flows allows reducing the aerodynamic resistance of the device by an average of 30%, depending on the mode of operation. This makes it possible to use dust fans with lower power in systems for dust collecting ventilation and, consequently, to reduce the energy consumption for the operation of these systems.

3. When installed in dust collecting ventilation systems of counter-twisted flows apparatus with suction from the hopper, the penetration of dust into the atmosphere is significantly reduced. At the same time, the concentration of dust at the level of the intake and the opening gates is correspondingly reduced, which makes it possible to reduce the costs of cleaning the air entering the rooms.

References

[1] Information on http://www.ac.gov.ru
[2] K. I. Strelets, M. B. Kitain, M. V. Petrochenko 2014 Welding Spark Parameters Determination for Cyclone Removal Calculation Advanced Materials Research. 941 pp. 2098-2103.
[3] N. Vatin, K. I. Strelets, N. Kharkov 2014 Gas Dynamics in a Counter flow Cyclone with Conical Nozzles on the Exhaust Pipe, Applied Mechanics and Materials. 635 pp. 17-21.
[4] S. T. F. C. Mortier [et al.], 2011 Mechanistic modelling of fluidized bed drying processes of wet porous granules, European journal of pharmaceutics and biopharmaceut. 79(2) pp. 205-225.
[5] N. Kharoua, L. Khezzar, Z. Nemouchi 2011 Study of the pressure drop and flow field in standard gas cyclone models using the granular model, International Journal of Chemical Engineering.
[6] Ch.-H. Hong [etc]. 2012 The effect of cyclone shape and dust collector on gas-solid flow and performance, International Journal of Chemical Engineering and Aerospace Engineering. 6 pp. 37-42.
[7] D.F. Ciliberti, B.W. Lancaster 1976 Performance of rotary flow cyclones International Journal of Chemical Engineering 22(2) pp. 499-503.
[8] C.N. Davies 1950 Lubrication theory for micropolar fluids, Proc. Phys. Soc. 63 pp. 288.
[9] A. N. Bogolomov, N. M. Sergina, T. O. Kondratenko 2016 On Inertial Systems. Dust Cleaning and Dust Removal Equipment, and Work Areas in the Production from Aerated Concrete from the Hopper Section Apparatus CSF, Procedia Engineering. 150 pp. 2036-2041.
[10] V. N. Azarov, N. M. Sergina, T. O. Kondratenko 2017 Problems of protection of urban ambient air pollution from industrial dust emissions MATEC Web of Conferences. 106 pp. 07017.
[11] V. N. Azarov, D. P. Borovkov, A. M. Redhwan 2014 Experimental Study of Secondary Swirling Flow Influence on Flows Structure at Separation Chamber Inlet of Dust Collector with Countercurrent Swirling flows International Review of Mechanical Engineering 8(5) pp. 851-856.
[12] I.V. Stefanenko, V.N. Azarov, N.M. Sergina 2017 Dust Collecting System for the Cleaning of Atmospheric Ventilation Emissions Trans Tech Publications Switzerland. 878 pp. 269-272.
[13] N. M. Sergina, E.A.Semjonova 2017 Settlement Assessment of Efficiency of Dedusting Systems with Dust Concentrators The Modern Science and the Innovations. 4(20) pp.137-142.
[14] V. N. Azarov, I.V. Stefanenko, N. M. Sergina 2018 Air flow straighteners’ application to reduce the power consumption of exhaust ventilation schemes, Applied Mechanics and Materials. The 2nd International Conference Material. 875 pp. 137-140.
[15] N. M. Sergina 2017 Environmental Efficiency, the Principles of Configuration and Reliability of the Dust Cleaning Systems with Vortex Apparatus with Counter Twirled Flows, Bul. VolgGASU. 50(69) pp. 106-114.
[16] N. M. Sergina, T. O. Kondratenko, M.A. Nikolenko, S.L. Pushenko 2017 The Principles of the Layout and Evaluation of Systems for Protection from Dust Pollution of the Air, Springer, Cham. 692 pp. 710-719.
[17] Sergina, N. M. 2013 Machines with counterclaims swirling flows with a suction from zone of bunker in the inertial dust collection systems Alternative power engineering and ecology 11 pp. 43-46.
[18] A.G. Bondar, G.A. Statyukha, I.A. Potyazhenko 1980 Experiment planning in chemical technology, Vysshaya Shkola, Kyiv.
[19] N.M. Sergina, T.A. Kislenko, E.A. Semjonova 2013 A system of purifying from dust for keramzit production Engineering bulletin of Don 4 pp. 1498
[20] N.M. Sergina, E.A. Semjonova, T. O. Kondratenko 2013 Ways of decrease in emissions of dust of lime to the atmosphere for production of construction materials Alternative Energy and Ecology 112,(43).
[21] N.M. Sergina, M.A. Nikolenko, T.O. Kondratenko 2015 Experimental assessment of the decision on decrease in dust emissions in the atmosphere in production of a gas concrete Engineering bulletin of Don 1 pp. 2751.