

# The Use of Coanda Effect in Energy-Efficient Recirculating Aspiration Systems

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**Abstract.** The article suggests an effective way for reduction of energy consumption of the aspiration systems by means of recirculating system with the use of Coanda effect. Operation of the system is organized with partial supplying of removed air from the aspiration hood to the reloading chute via the entry enabling to use Coanda effect. Thus, the supplied air moves in the direction opposite to ejection one and produces aerodynamic resistance reducing its volume that results in considerable reduction of the system's energy consumption. The article presents the results of the research enabling to evaluate the efficiency of the suggested engineering solution and the data necessary for its design.

## 1. Introduction

Different technological processes of production and processing of bulk solids in many industrial sectors including construction, mining, metallurgy, coal industry etc. are accompanied with intensive dust emission to the operating area [1-3]. This dust leads to development of a variety of occupational diseases. The major reason for spreading of the dust is ejection, i.e. air entrainment by the flow of the reloaded bulk solid [4-8].

The most effective ways for controlling of dust ejection are the systems for the complex dust extraction including aspiration systems, the means for prevention of the secondary dust ejection and general air change ventilation. It must be noted that, in this complex, it's the aspiration system that determines the necessary production capacity of the rest dust-extraction systems and therefore their energy consumption.

## 2. Actuality

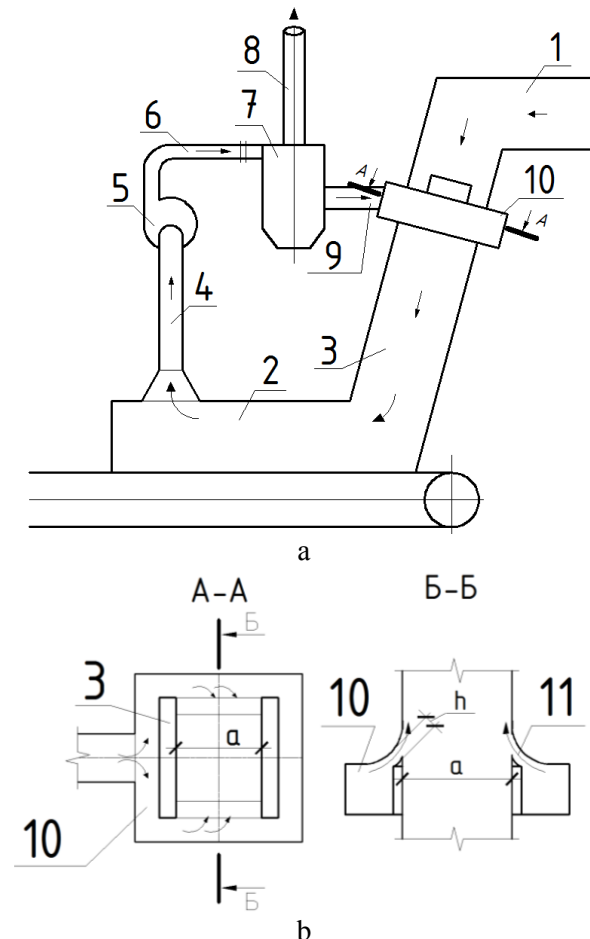
According to the researches, a number of enterprises spend up to 20% of their circulating assets [9, 10] for the maintenance of dust-extraction systems and that influences their competitiveness. The reason for that is, first of all, the use of non-effective engineering solutions and the faults in design. For example, most of enterprises still use single-wall aspiration hoods whereas they are characterized by low dust-cleaning ability and need high productivity of the system [11].

One of the perspective directions for reduction of energy efficiency of the aspiration systems is the use of recirculation principle [14, 15], alongside with the use of the modernized aspiration hoods [11-13]. Recirculation presupposes supplying of a part of the aspired air directly to reloading chute, Figure 1, a. Recirculating air compensates flowrate of the air ejected with the reloaded material that considerably reduces energy expenses to purification of the aspired air. When designing the unit in



question it is preferable that the recirculating air creates the greatest aerodynamic resistance to the ejected air.

There exist some modifications of the aspiration systems that use the principle of compulsory recirculation [15, 16], but they are characterized by a number of weak points. In connection with that the authors have performed the researches and, on their basis, it was improved the joint for supply of aspiration air to reloading chute of compulsory recirculation with the use of Coanda effect [17].



**Figure 1.** The principal scheme of the aspiration system with compulsory recirculation: 1. Upper aspiration hood; 2. Lower aspiration hood; 3. Reloading chute; 4. Aspiration pipe; 5. Ventilator; 6. Ascending pipe; 7. Dust control check unit (cyclone-dust concentrator); 8. Branch pipe for filtered air; 9. Bypass pipe; 10. Air-dust concentrate distributor; 11. Coanda air channels.

### 3. Task setting. Computation method

The record shows [11] that energy output of aspiration systems is characterized by their productivity rate of removed air. They influence the minimal volumes of removed air the aerodynamic resistance of the system of upper aspiration hood – reloading chute – lower aspiration hood. Low resistance of the system results in increased required system productivity and therefore increased power consumption.

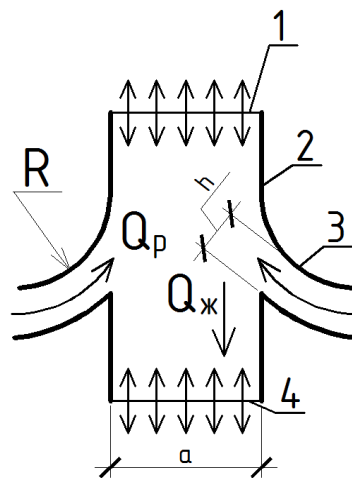
The work [15] establishes that reduction in losses of pressure in the tract of upper aspiration hood – reloading chute – lower aspiration hood leads to the growth in the volume of air moving through the chute, at any space and mode of recirculation flow supplying if it doesn't produce additional hydraulic resistance (distortions) in the way of the ejected air flow. On the basis of the drawn conclusions, it was suggested the mode of supplying of recirculation air providing the increase in hydraulic resistance of the reloading chute demonstrated at Figure 1, b. The increase in hydraulic resistance at the suggested

device is achieved by the use of Coanda effect [18, 19] when supplying recirculating air to the reloading chute.

The represented aspiration system works as follows. For provision of the sanitary-hygienic conditions at the areas of bulk solids reloading, i.e. non-ejecting of air-dust flow, air is exhausted from lower hood 2 by the ventilator 5 through the aspiration pipe 4; the air is supplied by ascending pipe 6 to the entry of the dust control check unit 7 for separation of air-dust concentrate. Filtered air is removed either to the atmosphere or to the next filtering step by the branch pipe 8, and air-dust concentrate is removed to distributor 10 of air-dust concentrate due to bypass pipe 9. Performed as a ring chamber, the distributor 10 of air-dust concentrate provides supplying of air-dust concentrate to the chute 3 via Coanda air channels 11. Herewith, due to a special form of Coanda air channels 11 providing Coanda effect, the flow of air-dust concentrate adheres to the chute that enables to increase the angle between the directions of air-dust concentrate movement and air dust flow moving in the chute. It can be explained by the fact that the surface of the chute 3 prevents from free access of air-dust flow on the one side of air-dust concentrate, and a part of air-dust flow is carried away on the other side of the flow. As a result, the aerodynamic resistance of the system increases that provides reduction in air consumption.

Research of the effectiveness of operation of the suggested construction unit was performed with the use of software application COSMOSFloWorks [20]. The complex uses in its operation continuity equation; Navier-Stokes and the energy of stationary three-dimensional flow in accordance with  $k-\varepsilon$  turbulence model.

The aim of the modeling exercise was determination of the optimal geometrical and aerodynamic parameters of the designed joint upon condition of minimal energy consumption.

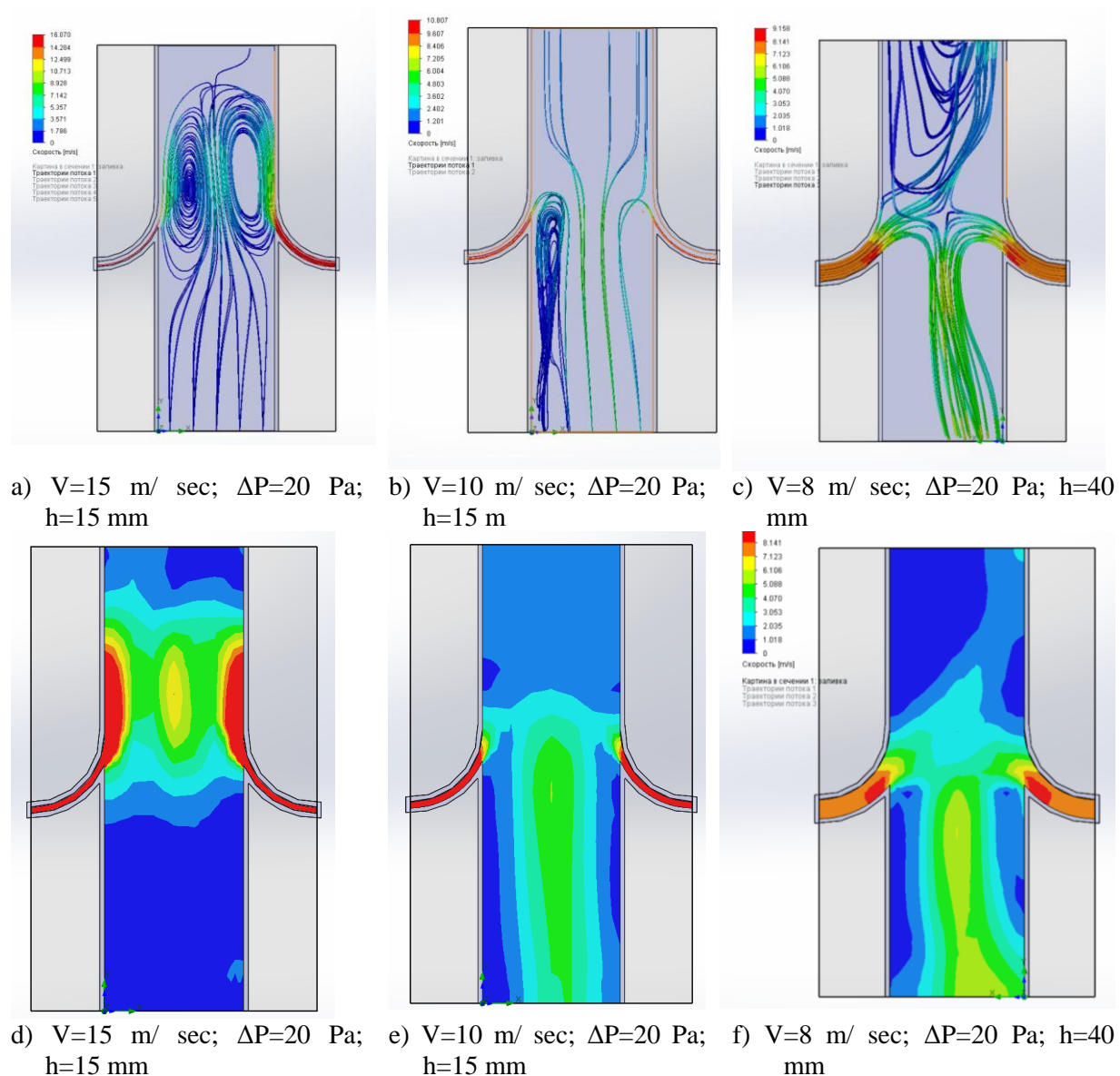


**Figure 2.** Border conditions of the modeling exercise: 1 – the surface of ejected flow input (pressure of 101325 Pa), 2 – the wall of aspiration hood, 3 – the entry of recirculating air to the aspiration hood, 4 – the surface of ejected flow output (pressure 101305 Pa).

In the research work, it was solved the inner task of air movement in the chamber of the vertical chute (height of 1000 mm from the upper to lower edge). For accomplishment of the task, they were made the initial conditions (physical parameters of the environment specific for normal conditions) and boundary conditions of the explored model. They were accepted as the boundary conditions 1 – spare surface, pressure of 101325 Pa, 2 – the walls of the aspiration hood, 3 – the entry of recirculation air to the aspiration hood, 4 – spare surface, 101305 Pa. It was accepted as the criterion of effectiveness the parameter of consumption of ejected air  $Q_{\text{ж}}$  via surface 4.

#### 4. The results of the research and its discussion

While executing the research they were revealed the factors influencing operation of the discussed construction unit, corner radius of Coanda channel  $R$ , the speed of the supplied air in the section of the Coanda channel  $V$ ; height of Coanda channel  $h$ ; width of reloading chute  $a$ . The researches were accomplished at pressure difference ( $\Delta P$ ) between surfaces 1 and 4 of 20 Pa that is true for most of cases of reloading sessions.



**Figure 3.** Partial graphic results of the modeling exercise for the designed unit: *a, b, c* for current streamlets, and *d, e, f* for the corresponding velocity fields

Some graphic results of the accomplished research are represented in Figure 3. The analysis of the obtained results leads to a conclusion that, at the specific aerodynamic mode of operation of the construction unit (Figure 3, a) they emerge steady vortices in the cross-section of the chute leading to immense reduction in consumption of ejected air. The mode appears at air speed of  $V=15$  m/sec and corner radius of inner edge of the channel of 160 mm. At lower speed of supplied air of  $V=10$  m/sec

(Figure 3, b.) it is observed carrying of the flow by ejection air that does not produce the necessary effect. They were also analyzed in the research the variants with modifying of the height of Coanda channel  $h$ , (Figure 3, c.). It was stated that when increasing the height of the channel  $h$  from 15 mm to 40 mm but at lower speed of  $V=8$  m/sec, despite higher consumption of supplied air by 1.4 times, it does not appear the intensive zone of turbulence as in case  $a$ , and it increases consumption of the air supplied to the hood. Thus, it can be concluded that it is the mode of operation in case  $a$  that promotes full realization of the opportunities of the suggested unit.

On the basis of the further performed research and processing of the obtained data it was revealed that the mostly effective work of the distributor appears at the following geometric parameters:

$$\frac{R}{a} = 1,8...2,1; \quad (1)$$

$$\frac{h}{R} = 0,09...0,11; \quad (2)$$

$$V = 13...16 \text{ m/sec.}$$

In the ratios (1, 2), they were used the relations of the geometrical parameters, for observation of geometrical and aerodynamic similarity in the units of other size.

The research has resulted in establishment of the fact that the use of the device in discussion enables to reduce to 80% the volume of the ejected air versus the systems without recirculation, and to 50% versus the analogical devices [15, 16]. Taking into account that usually even a small enterprise operates several aspiration systems, introduction of the suggested method of supply can be considerably effective.

## 5. Conclusions

The suggested method of organization of the recirculation flow enables to reduce energy input of the system's ventilator and electric energy consumption, in its turn, at the expense of reduction of the volume of the aspired air.

Alongside with pure economic reasonability, the use of the recirculating aspiration systems also promotes reduction of the harm to the environment.

Recirculation flow should be supplied to the loading chute with the use of the suggested design and following to all recommendations above. In this case the enterprise will considerably reduce its expenses to maintenance of the dust-extracting systems increasing energy-efficiency of the plant.

## 6. Conclusions

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### References

- [1] Howard L, Hartman Jan, Mutmanský M, Raja V, Ramani, Y J 1997 *Wang Mine Ventilation and Air Conditioning* (Wiley-Interscience) 752 p.
- [2] Logachev, I N, K I Logachev, 2014 *Industrial air quality and ventilation: controlling dust emissions* (Boca Raton: CRC Press) pp 417.
- [3] Huque S T, Donecker P, Rozentals J J, Benjamin C W 2010 *The Transfer Chute Design Manual: For Conveyor Belt Systems* (Conveyor Transfer Design Pty. Limited) p 272
- [4] Mallick S, Wypych P W 2010 *Evaluation of scaleup procedures using "system" approach for pneumatic conveying of powders* (Particulate Sci. Technol vol. 28) 1, pp 41–50.
- [5] Hastie D, Wypych P 2009 *Researching conveyor belt trajectories* (Engineers Australia vol. 81),

- 8, p 50
- [6] Li Xiaochuan, Wang Qili, Liu Qi, Hu Yafei *Developments in studies of air entrained by falling bulk materials* (Powder Technology, vol 291), pp 159-169.
  - [7] Chenchen Fang, Jianliang Xu, Hui Zhao, Weifeng Li, Haifeng Liu 2015 *Experimental investigation on particle entrainment behaviors near a nozzle in gas-particle coaxial jets* (Powder Technology vol 286), pp 55-63.
  - [8] Koichiro Ogata, Katsuya Funatsu, Yuji Tomita 2001 *Experimental investigation of a free falling powder jet and the air entrainment* (Powder Technology vol 115), pp 90-95.
  - [9] Kireev V M 2013 *Improving designs aspiration shelters to reduce dustiness Overload molding compounds in foundries: diss. ... Cand. tehn. Sciences, BSTU named after V.G. Shukhov.* (Belgorod)
  - [10] Kireev V M, Goltsov A B, Minko V A 2010 *Calculation and development of aspiration shelters for overload sites* (Nauch.-Teoret. magazine "Bulletin of BSTU. V.G. Shukhov ", 3), pp 114-117.
  - [11] Kireev V M 2013 *Improving designs aspiration shelters to reduce dustiness Overload molding compounds in foundries: diss. ... Cand. tehn. Sciences, BSTU named after V.G. Shukhov.* (Belgorod)
  - [12] Kireev V M 2010 *Aspiration shelter beds overload of bulk material* (Patent RU no. RU11 9743813 U)
  - [13] Goltsov A B, Kireev V M, Feoktistov A Yu 2013 *Investigation of the design of the aspiration shelter for use in cramped conditions* (Scientific-practical. journal "Ecology of Industrial Production", 1 (81)) p 2-5
  - [14] Logachev, I N 2015 *Local Exhaust Ventilation: Aerodynamic Processes and Calculations of Dust Emissions*, (Boca Raton: CRC Pres)
  - [15] Ovsyannikov Yu G 2013 *Aspiration systems with forced recirculation: monograph* (Belgorod: BSTU Publishing House) pp 137
  - [16] Ovsyannikov Y G, Gol'tsov A B, Seminenko A S, Logachev K I, Uvarov V A 2017 *Reducing the power consumption of ventilation systems through forced recirculation* (Refractories and Industrial Ceramics, vol 57), 5, pp 557-561
  - [17] Ovsyannikov Yu G, Goltsov A B, Seminenko A S, Kireev V M, Burianov I A, Zhilina S S 2018 *Patent 177236 RF Shelter with recirculation of aspirated air* (2017112163, filed. 10/04/2017, publ. 02/14/2018)
  - [18] Seminenko A S 2018 *Experimental facilities for determining the conditions for the implementation of the Coanda current* (Bulletin of the Belgorod State Technological University), 3, pp 52-59
  - [19] Logachev I N, Logachev K I, Uvarov V A, Seminenko A S, Goltsov A B, Kireev V M 2016 *Velocity field for fan weakly swirled jet of loading spouts for fine materials* (International Journal of Pharmacy and Technology vol 8), 4, p 24880
  - [20] Kireev V M, Minko V A, Logachev K 2012 *Use of program complexes in research of the work of aspirating shelters* (In the collection: Energy saving and ecology in housing and communal services and construction of cities) p 50-54