Ensuring the protection of the environment at the combined feed mills

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Abstract. There is a great amount of technological lines producing the combine feed of various compositions, forms and consistency, what dramatically effects on the condition of the environment; during the process of its producing the significant emission of the plant- and mineral-based dust happens; that is why the development of the complex of the systemic events “dust-removal - dedusting” is so significant. The article is devoted to one of the elements of this system – the process of the dust removal. The projected system as well as the laboratory facility for studying the effectiveness of the aforementioned system, and the results of the laboratory experiments allow to low the dust emission at the combined feed mills.

1. Introduction
At the combine feed mills where the implementation of the technological processes is tightly connected with the dust spreading into the factory rooms and the environment, it is necessary to ensure the high effectiveness of the ventilation and aspiration units. The effectiveness and the safety at the mill, the effectiveness of the dedusting equipment, and as a result the protection of the environment depend on the level of development and reliable work of the units highly depend on the unit level of development and its reliable work. The material for the manufacturing the combine feeds is the granular material as the granular (wheat, oat, barley, corn) and grist (soy, sunflower). A great amount of mineral- and plant-based dust forms during the process of the auto transport off-load with the further emission of it into the receiving point and dispersion in the environment by the wind streams [1]. The multiple exceedance of the maximum permitted concentration (MPC) in the air of the working zone leads to the workers’ occupational illnesses, has a negative impact on the equipment, poses the danger of explosions, and pollutes the environment [2]. One way of the response on the high level of dust is designing the dust removal system, which allows to improve the workers’ labour conditions and decrease the pollution of the environment at the receiving points of the elevator without making adjustments in the well-oiled technological process thanks to rational meanings of time of turning the projected dust removal system on [3-5].

2. Canalizing the studies in this field
At the current moment there are different ways and methods of fighting with the high level of dust in the working area [6-14]. These are the most important: sealing the equipment, humidification of the air and the dust-making material, cleaning the surfaces of the room equipment, improving the ventilation system. As the possibility of dust cloud forming cannot be totally excluded, in many cases the systems of exhaust ventilation and aspiration are implemented. As for the dump pits, the machines for dedusting
at the stage of the off-load the granular materials unto the receiving bunker are used [11-13]; their usage is connected with the following:

- decreasing of the effectiveness of the dedusting in some time due to the gutter-formed dedusting storage slot, what can lead to the increasing of the flow resistance of the aspiration system;
- the absence of the visual controlling the dust filling with the granular material due to the plate fixed over the bunker and the entry valve, what can lead to the disruption of the technological process.

3. Studying the production lines of the combine feed mills

3.1 The aim of the research is to ensure the protection of the environment at the combined feed mills.

The main tasks of the research are the following:

1) Theoretical reasoning of the ensuring the protection of the environment at the combined feed mills;
2) Designing the dust removal system at the stage of the off-loading the granular material into the receiving bunker and constructing the experimental laboratory facility for conducting the research of the dust removal system effectiveness in order to obtain the mathematical models which describe the correlation between the dust concentration, the effectiveness of the dust removal system use and the condition of such a system (turning off and on in advance or at the same time with the sliding of the wheat granular material); also suggest the methods of constant measuring the level of dust in the air.

Decreasing the level of dust $c_w$ in the waste is connected with the dust concentration $c_f$ in the air incoming to the treatment facilities [15, 16]:

$$c_w = f(c_f).$$ (1)

Dust concentration $c_f$ in the air incoming to the treatment facilities is determined by the mass of the dust $m_n$ which got into the air of the receiving point, and $m_y$ - the mass of dust being deleted by the dust removal system from the air of the receiving point:

$$c_f = f(m_n, m_y).$$ (2)

The mass of the dust $m_n$ incoming into the air of the receiving point, is constant, the mass of the deleted dust $m_y$ depends on the dust characteristics (size of the $\delta$, particles, the absolute density of the dust $\rho_p$, the number of the particles $n$) and the modes of the dust removal system (the air consumption $L_{ac}$ which is also constant), so the equation can be written in this way [5]:

$$m_y = L_{ac} f(n, \rho_p).$$ (3)

The number of particles $n$ and the size of ones $\delta$, being deleted by the dust removal system is defined with the effectiveness $E_d$ of the dust removal system, therefore, the equation (1) looks like this:

$$c_w = L_{ac} m_n f(E_d, \rho_p).$$ (4)

The projected dust removal system at the stage of the off-load the granular materials into the receiving bunker [16] helps to increase the effectiveness of the dedusting in some time, ensure the visual control of the bunker filling process. It happens due to this situation: at the beginning of the auto transport off-load 1 the operator turns on the centrifugal fan unit 2, the granular material 3 comes to the receiving bunker 4. At the same time the dust cloud 5 is forming; it consists of little flying dust fractions, coming to the aspirational dedusting suction tools 6 in the upper part of the fixed plate 7 placed on the frame 8, and going further through the aspirational tube 9 into the dust collector of the cyclonic type 10 (figure 1).

Depending on the speed, the direction of the wind, and the concentration of the dust, which are controlled by the speed and wind direction sensor 11, placed over the antirain cover 12, and dust sensor 13, with the control unit 14 of the electric engine 15 the productivity of the centrifugal fan unit is regulated. While lowering the level of the dust concentration to the required limits at the off-load of the transport in the operator’s and administrating zone the automatic cut-down of the centrifugal fan unit happens after the signal from the dust sensor with use the control unit of the electric engine.
Figure 1. The dust removal system at the stage of off-loading the granular material to the receiving bunker: a – the scheme of the dust removal system at the stage of off-loading the material into the receiving bunker; b – top view of the dust removal system at the stage of off-loading the material into the receiving bunker.

In order to study the process of outflow from bunkers of the granular materials the experimental facility was constructed (figure 2-3, (a) and (b)), and the methods of the research were defined [3, 4, 18].

The result of the research is demonstrated on the figure 4 (a-c); the distribution of the levels (experimental) of the dust concentration was obtained, as well as the dust concentration meanings according the approximating equations (5) and the effectiveness of the dust removal system usage.

$$y = b_1 x^6 + b_2 x^5 + b_3 x^4 + b_4 x^3 + b_5 x^2 + b_6 x + b_7,$$

where $b_1, b_2, b_3, b_4, b_5, b_6, b_7$ are the coefficients of the approximating equation (table 1).

Figure 2. Scheme of the laboratory facility for exploring the effectiveness of the dust removal system: a – general view; b – scheme of the dust formation and the dust removal; 1 – body, 2 – dust chamber, 3 – receiving bunker, 4 – load bunker, 5 – valve, 6 – off-load bunker, 7,8 – dedusting suction hoods, 9 – fan unit, 10 – air cleaner (cyclonic type), 11 - 12 – optical sensor; 13 – transmitter, 14 – aspirator, 15,16 – allonges with the analytical filter, 17 – power unit, 18 – PC, 19 – meteoscope; $L_w$ - the volume of air consumption by the dust removal system (86 liters per second), $V_{v}$ – the speed of air streams created by the dust removal system by the place of off-load, $V_{v_{p}}$ – the speed of the dusty air.
Figure 3. Laboratory facility of the dust removal system at the stage of off-loading the granular material into the receiving bunker: a – backwards view, b – towards view.

Figure 4. The results of the experimental researches of the dust removal system:

a) the experimental level of the dust concentration: I – the period of the spitting dust emission with the extremal forming and lowing the level of concentration; II – the period of steady deposition of the dust and steady lowing the level of concentration;

b) the level of the dust concentration taking into account the approximating equations: 1 – with the turned-off dust removal system; 2 – with the turned-on dust removal system (simultaneously with the beginning of the wheat sliding); 3 - with the turned-on dust removal system (30 sec before the beginning of the wheat sliding); with the turned-on dust removal system (60 sec before the beginning of the wheat sliding);

c) the effectiveness of the dust removal system use: A is for speed of lowing the level of the dust concentration (approximating); B is for time of the gap between the max and min of the dust concentration (approximating).
### Table 1. The coefficients of the approximating equation (5)

| $b_i$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
|-------|--------|--------|--------|--------|
| $b_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $b_2$ | -0.0003 | -0.0005 | -0.0003 | -0.0004 |
| $b_3$ | 0.0370 | 0.0567 | 0.0382 | 0.0460 |
| $b_4$ | -2.5773 | -3.3049 | -2.0844 | -2.8875 |
| $b_5$ | 81.4245 | 72.9177 | 36.0898 | 71.4798 |
| $b_6$ | -25.7061 | 273.7142 | 889.4535 | 411.0352 |

At the dedusting process (figure 4 (a)) two stages need to be mentioned. The first stage is the spitting dust emission with the extremal forming and decreasing the level of concentration for 3 conditions of the dust removal system (turning on the dust removal system at the same time with the beginning of wheat sliding, turning on the dust removal system 30 sec before the beginning of wheat sliding, turning on the dust removal system 60 sec before the beginning of wheat sliding) except the turned-off condition of the dust removal system (1), where the process of extremal forming the concentration of dust takes place, and the decreasing of the level of concentration happens lower than in cases 2,3,4; the second stage is the steady deposition of the level of the dust concentration together with the oscillation process in one way or another.

The figure 4 (b) depicts the graphical relations according to the approximating equations (5), which prove the experimental data with the high level of credibility (figure 4 (a)).

The figure 4 (c) depicts the graphical relations of the dust removal system effectiveness; lowering the level of concentration per a degree (approximating) is A (according to the equation (6)); the speed of the lowering the dust concentration is B (according to the equation (7)).

$$y = -5.9000x^3 + 41.7523x^2 - 81.5737x + 47.8239; \quad (6)$$

$$y = 35.833x^3 - 258.000x^2 + 488.167x - 78.000. \quad (7)$$

Graph B demonstrates that as the condition of the dust removal system changes from its turning off (1) to its turning on 60 sec before the beginning sliding the wheat, the time meaning of the lowering the concentration of dust minimal at turning on the dust removal system 45 sec before the wheat sliding begins. Graph A demonstrates that as the condition of the dust removal system changes from its turning off (1) to its turning on 60 sec before the beginning sliding the wheat, the time meaning of the lowering the concentration of dust is maximal at turning on the dust removal system 40,5 sec before the wheat sliding begins.

3.2. Estimating the implementation of the dedusting system in the off-load of the granular materials into the receiving bunker

To conclude, the technological process with the dust removal system use at the stage of the off-load the granular materials into the receiving bunker, mathematical models setting the relations between the level of the dust concentration, the effectiveness of the dust removal system use and the conditions of the suggested system (turning off and on simultaneously or in advance with the sliding the granular material) can ensure the protection of the environment at the combine feed mills.

### 4. Conclusions

The dust removal system while off-loading the granular materials into the receiving bunker, the mathematical models of determining the level of dust concentration, the effectiveness of using the dust removal system, and the methods of constant measuring the level of dust in the air can be recommended for the practical use while reconstructing the existing receiving points at combined feed mills and designing the new ones.
References

[1] Smolnikov D O 2016 Modernisation of the aspirational systems J. Kombikorma [Combine feed] 1 62 – 4

[2] GOST 12.1.041-83 Fire and explosion safety of combustible dusts. General claims 1983 (Moscow: Gosstandart) p 30

[3] Belova T I, Agashkov E M, Chernova E G, Terekhov S V, Loboda O A Experimental research of improving the labour conditions of workers at the receiving point of the combine feed mills Proc. Int. Conf. (Belgorod: BSTU named after V.G. Shukhov) 31-8

[4] Belova T I, Agashkov E M, Chernova E G, Terekhov S V 2018 Increasing the effectiveness of the exhaust equipment usage in dust removal system at the stage of the off-load the granular materials of the combine feed mills Proc. Int. Conf. “Technosphere safety in the agriculture industry” (Orel: Orel SAU publishing center) 38-45

[5] Belova T I, Agashkov E M, Gavrishchuk V I and et al. 2017 Decreasing the dust level at the stage of the off-load the granular materials J. Selskiy mekhanizator [Country Mechanizer] 5 24-5

[6] Shtokman E A 1989 The air purification at the factories of the food industry (Moscow: Agropromizdat)

[7] Logachev I N, Logachev K I 2005 Aerodynamic characteristics of the aspiration (Saint Petersburg: Khimizdat)

[8] Dmitruk E A 1987 Fighting with the dust at the combined feed mills (Moscow: Agropromizdat)

[9] Fuks N A 1955 Aerosol mechanics (Moscow: Academy of Sciences publishing center)

[10] Posokhin V N 2008 Aerodynamics of the ventilation (Moscow: AVOK-PRESS)

[11] Device for the dedusting at the stage of the off-loading the granular material into the bunker 1988 Patent of the USSR № 411980/22-11, appl. 28.06.1986; publ. 15.02.1988 p 3

[12] Device for the dedusting in the collector bunkers 1991 Patent of the Russian Federation № 5017946/11, appl. 02.07.1991; publ. 27.10.1995 p 4

[13] PETKUS Technologie GmbH. On line at: http://www.petkus.com (date of the request 22.05.2019)

[14] William Benjamin Williams 2014 Source Apportionment and Dispersion Mapping of Fugitive Dust using Directional Passive Monitors The thesis in portal fulfillment of the requirements for the award of the degree of Doctor of the University of Portsmouth

[15] Meier Th, Kolagar A H, Echterhof Th 2018 Pfeifer Process Modelling and Simulation of an EAF and its Dedusting System (Moscow: Chernye Metally)

[16] Li Xiaochuan, Wang Qili, Liu Qi, Hu Yafei 2016 Developments in studies of air entrained by falling bulk materials J. Powder Technology 291 159-169

[17] Belova T I, Agashkov E M, Terekhov S V, Chernova E G 2018 The receiving point of the elevator Patent of the RF №2017133586

[18] Yermoliev Y I 2003 The basics of the scientific research in agriculture machinery (Rostov-on-Don: DSTU publishing center) 82-5