Reconstruction of electromechanical device for blocking dust emissions

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Abstract. As a result of the work, a new configuration of the electrode system was investigated based on the application of the particle behavior prediction method. The new configuration of the electrode system allows for a lower supply voltage to increase the bulk density of the electric field charge in the interelectrode space, to increase the time of the dust particle in the interelectrode space, and also reduces the risk of electrical discharges on the corona electrodes. Calculation on the developed special software product was made for different geometry of the interelectrode window (120, 150, 200 microns). Computer simulation of physical processes in the interelectrode space, analysis of the dynamics of the charge set by the dust particle, as well as calculation of the forces acting on the dust particle confirmed the efficiency of the chosen geometry of the electrode system.

1. Introduction
Lack of many devices which are earlier developed and applying to the display corona discharging category to blocking of dust fractions consists in the insufficient area of to the display corona discharging electrodes and small time spent of a particle in a zone of to the display corona discharging electrode.

Technical task of the offered device consists in increase in effectiveness of suppression of dust emissions for decrease in environmental of various technological objects, at decrease energy consumption and mass-dimensional indicators of the device.

The possibility of the solution of an objective is reached by change of geometry of an electrode system. In difference from earlier studied configuration of the electromechanical device of suppression of dust fractions of needle type, the offered option of a design provides increase in the area of influence of to the display corona discharging electrode, increase in the time spent of a dust particle in a scope of an electric field and also indirect mechanical suppression of driving of dustair mix.

2. Main part
At the expense of that, to the display corona discharging electrode is executed from the separate plates bent at an angle connected to the negative electrode of the power supply an apparent density of a charge in interelectrode space increases at the expense of additional streamer streams and by that receiving time dust particles of the limit charge decreases, the time spent of particles in the field of a corona discharge increases and also the effort from an electric field increases.
In turn the form-building electrode is made in the form of a grid of unmagnetized material of the steam-and-gas mixture tense perpendicular to a stream and connected to a positive pole of a source of high-voltage tension.

Figure 1. The scheme of driving of dust streams in the electromechanical device of suppression of dust fractions of blinds type

We will practically not distinguish the principle of action of this design from early configurations of electrode systems. Dustair mix, after a cyclone moves in the bunker in the perpendicular direction to the form-building and to display corona discharging electrodes. In the course of passing through interelectrode space each particle of dustair mix carries out accumulation of a charge. With increase in a charge in process of passing of a way from a form-building electrode to the display corona discharging electrode the braking effect amplifies. Additional effect of application of this configuration is the design of to the display corona discharging electrode which is providing the larger area of a covering and mechanically stopping movements of dust particles. However It should be noted that this effect isn't the basic. By results of model operation it is possible to tell that the most efficient will be that geometry of an electrode system at which the stop and redirection of driving of dust particles will be carried out before contact of particles with to the display corona discharging electrode that will allow to reduce negative effects of possible categories. Achievement of this effect will allow to apply installation in more adverse conditions with the explosive environment, for example, in case of application of installation in mines to purification of air.

Within realization of the real work various options of designs of the electromechanical device of suppression of dust emissions are investigated. Input datas, applicable to all researches of a chapter 3, were divided into the following groups.

- the unchangeable specifications determined by technological process.
- the unchangeable specifications determined by parameters of a power line and design features of the considered device: - a delivery is carried out from single-phase network by tension U = 220 V / 30 kV with f frequency = 50 Hz / 0 Hz (reverse polarity); cleaning of working parts – air.

In the considered options of devices of blocking of dust emissions a number of the physical processes having direct impact on overall performance of this type of devices proceeds.

For determination of design data of the device at which its effective functioning is ensured it is necessary to use mathematical model operation of physical processes in the device.

Mathematical model of electric processes of the dust fractions arising in the fissile region of the electromechanical device of suppression:

\[
\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = -\frac{\rho}{\varepsilon_0},
\]  
(1)
The approach based on use of a finite element method was applied to calculations.

In the course of calculations the finite element method, for a single particle of dust fraction carried out calculation of the charge acquired by it at stay in a particular point of space with coordinates \((x, y)\). For each point of space taking into account the acquired charge the particle, carried out calculation of all accompanying efforts and the balance of forces was checked.

Realization of the above described calculations allowed to receive characteristics of the physical processes arising in the fissile region of an electrode system of the electromechanical device of suppression of dust fractions and also to estimate behavior of particles of the dust fractions which are carrying out immediate driving in an action field of a corona discharge. The main difference from earlier developed and applied techniques is the possibility of accounting of "ionic" wind.

Within this project model operation of physical processes and assessment of behavior of particles of fine fraction in the fissile region of an electrode system of the electromechanical device of suppression of dust fractions for the available design of the experimental exemplar "needle plane" was carried out that in subsequent allowed to confirm adequacy of the chosen method of assessment of behavior of fine fraction.

Calculation of dependences was performed with use of a finite element method, for a trajectory of driving of a particle of fine fraction. For exact realization of the functions, calculation was carried out for the worst provision of a dusty particle in the fissile region of an electrode system in which it is affected by minimum effort from an electric field.

In figure 2 the electrode system of the electromechanical device of suppression of dust fractions is represented. The electrode system is executed from two types of electrodes: to display corona discharging, presented by plates with sawtooth edges and form-building in the grid form. At power connection to an electrode system, the negative to the display corona discharging electrode and positive to a form-building electrode, in a zone of interelectrode space volume electric charge is created. As a result the electrode system creates two multidirectional efforts that is caused by a configuration and arrangement of electrodes. The dominance of an axial component of electric forces leads to an expulsion of particles of dust from a gap between in parallel the located precipitation electrodes which are bound to a positive pole of a source of high tension. Because to the display corona discharging electrode consists of plates the time spent of dust particles in an area of coverage of to the display corona discharging category increases that leads to increase in effectiveness of a lock.
Thus, the electromechanical device of suppression of dust fractions with the improved characteristics blocks driving dust parts at the free exit of scrubbed gas that provides prevention a diversity of dust and keeping of dust particles in a dusting source zone.

For a lock of this type, in view of construction features, it makes sense to consider processes only in an interelectrode window between to the display corona discharging electrodes. In this research model operation of physical processes for a new design of the device was carried out. Results of the carried-out calculations of dynamics of charging of the particles and efforts operating in this electrode system at change are given below:

- interelectrode space of to the display corona discharging electrodes relatively each other.
- sizes of a particle of fine fraction.

Table 1. Dynamics of enrollment of a charge a particle of fine dust fraction depending on the sizes of an interelectrode window

| Entrance to the fissile region | Interelectrode window of 150 mm | Interelectrode window of 200 mm | Interelectrode window of 120 mm |
|-------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 50 mm                         | 3,57752E-13                     | 3,08703E-13                     | 3,11245E-13                     |
| 100 mm                        | 7,11909E-13                     | 6,11325E-13                     | 6,19361E-13                     |
| 150 mm                        | 1,057E-12                       | 9,02139E-13                     | 9,1959E-13                      |
| Guaranteed stop line          | 1,3818E-12                      | 1,17343E-12                     | 1,20216E-12                     |
Figure 3. Dynamics of enrollment by a dust particle of a charge

Table 2. Calculation of effort from an electric field, acting on a particle of fine fraction, depending on geometry of an interelectrode window.

| Entrance to the fissile region | Interelectrode window of 150 mm | Interelectrode window of 200 mm | Interelectrode window of 120 mm | Pressure force from a stream |
|-------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------------------------|
| 50 mm                         | 2,12E-09                        | 1,58E-09                        | 1,85E-09                        | 2,51E-09                     |
| 100 mm                        | 4,14E-09                        | 3,01E-09                        | 3,6E-09                         | 2,51E-09                     |
| 150 mm                        | 5,73E-09                        | 4E-09                           | 4,99E-09                        | 2,51E-09                     |
| Guaranteed stop line          | 6,05E-09                        | 4,14E-09                        | 5,26E-09                        | 2,51E-09                     |
Figure 4. The effort from an electric field operating on a particle of fine fraction depending on geometry of an interelectrode window for the purpose of confirmation of adequacy of a mathematical apparatus of the developed model and correctness of its assumptions the experimental check of theoretical results of model operation was executed.

Table 3. Observed datas on the designed installation of blocking of dust emissions.

| Parameters                          | Unit of measure | The device is switched-off | The device is switched-on |
|------------------------------------|-----------------|----------------------------|----------------------------|
| Air temperature in the place of measurement | °C              | 38                         | 38                         |
| Air speed on a pollution           | m/s             | 1.38                       | 1.02                       |
| Production time of tests           | min             | 3                          | 20                         |
| Quantity of an aspiring air on emission | m³/c          | 370                        | 320                        |
| Concentration of dust              | mg/m³           | 469.2                      | 8.1                        |
| Amount of dust in a stream         | g/s             | 0.046                      | 0.0009                     |
| Extent of cleaning                 | %               |                            | 98.27                      |
Research and development of the new power supply will become an important factor of increase in overall performance of the electromechanical device of suppression of dust fractions. The analysis of scientific publications showed that success in creation of highly effective devices achieved in recent years with extent of purification of dust-air mixes to 98 – 99% is inseparably linked with perfecting of units of a delivery and an intensification of the modes of their work.

Polarity given on to the display corona discharging tension electrodes the negative. It is bound to the fact that at the negative polarity of value of breakdown voltage of a working interval of the device is much higher, than at positive.

Regulation of tension of the unit is made, as a rule, in indirect parameters, such as average tension, frequency of scintillations, power and so on.

The overall performance of the electromechanical device of suppression of dust fractions as practice shows, in essential degree depends on a regularity of the choice of a diet of the unit: the form of power voltage caused by a rectification circuit, a way of regulation of tension, level of electric parameters, the scheme of turning on of the unit on loading. The diet in turn is defined by type of the dust caught in the device, properties of the dust environment, a design of the electromechanical device of suppression of dust fractions, features of operation of units in the mode of breakdowns. As show the pilot studies on the electromechanical device of suppression of dust fractions of needle type, at achievement of a defined critical value of tension extent of cleaning practically doesn't change at increase in current and tension or can even decrease, at the same time insignificant breakdowns were observed. This effect can affect negatively at application in rooms with the explosive environment, for example in mines.

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