Automated control system of industrial dust suppression process

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Abstract
To reduce or suppress industrial dust there used irrigation by liquid solution. This dust suppression technology is based on the idea that the moistened dust becomes heavier and sinks under its own weight on the floor. This technology only partially solves the problem since it does not provide complete suppression of dust in the environment. Disadvantages of other known methods and devices are great and irrational use of the liquid solution, which is required for irrigation, and low efficiency of dust suppression.
To improve the efficiency of protection from industrial dust, improve occupational safety and pollution prevention in modern enterprises there created and implemented a variety of innovative technologies and applied new technical means to suppress dust. Therefore, it is suggested on the basis of theoretical justification, to use more effectively technological equipment, which is in commercial operation.
To do this, it is suggested to add to installation for dust suppression automated control system equipment with usage of modern microprocessor technology, large-scale integrated schemes and primary converters. The main problem solved by modernizing is to increase the efficiency of dust suppression by automatically control of the supply of positively and negatively charged water as a function of determination of the amount of dust in the air and there offered depending on the dispersion of industrial dust according to a special algorithm to include optimal number of nozzles.
Key words: INDUSTRIAL DUST, LIQUID SOLUTION, SETTING TO SUPPRESS DUST, AUTOMATED SYSTEM

The problem and its relation to scientific and practical tasks

Conversion of iron ore in mining, ore dressing and metallurgical enterprises of Ukraine is a complex technological process associated with the transformation of raw materials into various states and obtaining new physical and mechanical properties. These include crushing, beneficiation and agglomeration factories, waste rock and ore storage, roads, boilers, areas with no vegetation, and others. In order to ensure the right technology industrial dust, there used at enterprises equipment and auxiliary machinery of varying degrees of complexity. In many cases, these processes are accompanied by the release of large amounts of airborne solid or liquid particles, which in scientific terminology are called as aerosols or aero disperse systems, and that for the sake of simplicity, we will refer to industrial dust, and where necessary to clarify the use of terms. Source of industrial dust is one of the largest and specific pollutants, almost all the components that make up the biosphere, high concentrations of which is harmful for human health, forests, agriculture and others. A significant influence on the atmosphere of companies as a whole and its separate sections make availability, composition and nature of the moving air currents, which in many cases determine the amount brought ones, arising and removed from the hazards of industrial facilities, and sometimes are a cause of intense dust formation.

Industrial dust - is the smallest solid particles released during crushing, grinding and mechanical processing of various materials, loading and unloading of bulk cargo, etc. and are inorganic material, which is divided into mineral (quartz, cement and others.) and metalic (steel, cast iron, copper, aluminum and others.). According to the location sources of dust are divided into internal and external. Internal sources include: drilling rigs and rock drills, excavation and loading machines, blasting, internal combustion engines (dump trucks, locomotives, tractors, bulldozers, and others.), roads, stone cutting machines, crushing and screening plants, as well as the areas covered with dust and which are subjected to weathering. External sources are located outside the enterprise. Under the action of wind, dust from these sources may be distributed in the environment, the overall deteriorating condition of the atmosphere. A significant part of industrial dust is of mixed origin, it consists of particles of organic or inorganic and, when organic, includes metal particles and mineral dust. This should be considered when choosing treatment methods and composition of the equipment, industrial suppress dust. The complexity is determined by the fact that enterprises located in different climatic regions, have different geological conditions and parameters, and spend minerals and host rocks with different physical and mechanical properties and mineralogical composition, and other factors. In addition, the problem solution of industrial dust suppression is further complicated by the fact that during mining operations there produced and secreted particulate dust with different properties, neutralization of which requires a differentiated approach. Reduction of evaluation or complete suppression of industrial dust in the environment, which is one of the main sanitary and environmental requirements, is an urgent problem, solution of which is directly related to the scientific and practical issues of improving the methods of calculating the concentration and separation or suppression of dust scattering from major sources. Herein application of dust suppressants dramatically reduces environment dust.

Analysis of research and publications

Known devices for dust suppression used in the mining industry, which operation is based on irrigation of processed rock mass in acceptance reloading bunkers, on the conveyor, crushers, etc. [1]. In other studies [2-4] the basic physical and chemical phenomena occurring on the border between solutions, rock particles and gases, which provide effective suppression of dust and gas to open mine development are determined. The research of environmental performance when used to blast rocks demolition explosive ammonites is fulfilled and ways for emissions reduction generated by pollutants are chosen and the method for suppressing dust and gas during mass explosion in quarries is suggested. Scientific approach to the choice of means for suppress of dust during mass explosion in quarries was deleloped[5], as it was found that the basic properties of solutions, which can affect the efficiency of dust suppression, is to reduce the surface tension on the surface of rocks, dust and coagulation ability to bond fine particles of rocks.

For dust removal of broken rock mass in the quarries there used an installation [6], which includes mainly installed on a vehicle that has an exhaust pipe, propeller-driven rotor, water tank, pump and piping for water distribution devices connected with the nozzles. This installation is also provided with an air compressor connected to the

nozzle and the pump is provided with a protective casing to which pipes are connected to the exhaust of the vehicle. This setting is located on a heavy vehicle, which requires soil with a high load capacity, making it impossible to use for dust control on the storage of industrial waste. Furthermore, the use of a propeller-driven rotor creates a vortex at the dust dusty surfaces, reduces the working efficiency.

Also known system for dust suppression [7] on surfaces with low bearing capacity, for example, storage of industrial waste, mining, energy and other industries. Installation for dust suppression contains a basic vehicle as the platform , which towed and located on the working fluid container with a pump, the rotary drum. Circular device is mounted on a rower, and is associated with the pump and the pressure pipe to a flexible hose wound onto the drum rotates.

Currently there known settings and means to suppress dust, for example, [8], which uses concentrated solutions after regeneration of filters that are cations and contain 15-20% of complex salts ($CaCl_2$, CaSO4, Ca (HCO3) 2, MgCl2, MgSO4, Mg (HCO3) 2, NaCl, Na2CO3, etc.). However, the use of this tool is complicated due to the lack of efficient equipment for its application to large areas of surface dust.

Article [9] is devoted to the efficiency of dust collection. It contains theoretical studies of precipitation, which is inertia, in the means dust, which is captured, it is shown as a function of the initial concentration and dispersion, as well as provides results of experimental studies and there proposed ultrasonic coagulation.

As shown in [10-16], it is known that the reduction of dust can be performed by irrigation with a solution of industrial dust storable fluid. Here are applied spraying water in the form of a fine mist in places where there is dust in order to reduce its concentration, which can acquire the risk of dust explosions and ecological condition of the area to prevent silicosis - black lung disease in miners, or other diseases. This dust suppression technology is based on the idea that the moistened dust becomes heavier and sinks under its own weight on the floor. Such technology dust suppression only partially solves the problems arising from the dust in the air companies.

The disadvantages of methods and devices is no longer rational use of water flow that is needed for irrigation, and low efficiency of dust suppression.

Statement of the problem

The aim is to create and implement innovative technology and modern means to suppress dust in warehouses iron metallurgical enterprises based on theoretical grounds. This will allow the productive use of technological equipment that is in commercial operation, by improving its performance by implementing automated control system of the new generation, which is built on modern microprocessors, integrated circuits and large primary converters. The introduction of such technical solutions will enhance the fight against industrial dust, improve health and safety and prevent pollution in mining enterprises.

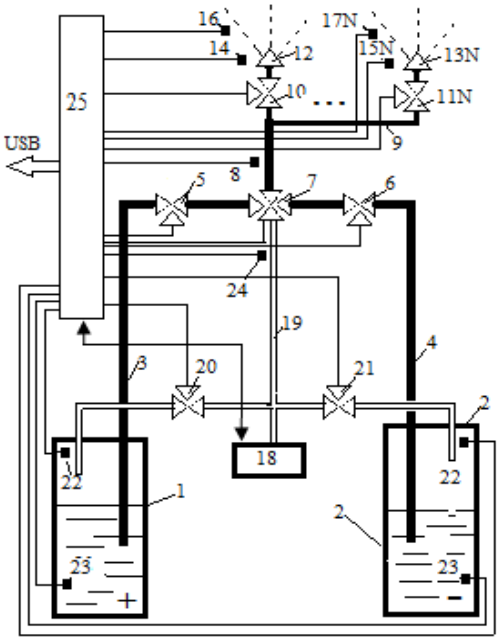

Figure 1. Block diagram of the control device for suppressing dust

Presentation of the material and results

To date, the level of automation of the enterprises is growing steadily. With the introduction of advanced automated systems not only the quality and quantity of the products are improved, but also the environmental performance of companies. At the moment the most common and effective way of dust suppression is irrigation, which is related to technical measures. Dust suppression effectiveness using irrigation increased ionized water, for instance water, as the electrically charged dust particles [11]. To suppress dust, the ionized liquid is fed under high pressure through pneumatic and hydraulic nozzles that provide great long-range water flow and spray a thin jet of water. Sometimes use special nozzles gun, which form a powerful jet of water from the trajectory angle of

25 °, which is very resistant to wind and remains effective even at low temperatures (up to - 30 ° C). The liquid is fed directly to the place of formation of dust, covering a total area of occurrence of dust, but it is desirable to have an automated control system that allows you to realize fully dust suppression at the rational use of water spray. Using known technology, such as patented invention [12], it is proposed to improve it. The block diagram of the system is provided in Figure 1. The scheme includes: tanks 1 and 2, which are in the shape of siphons for ionized water (respectively positive and negative polarity); main line 3 and 4 respectively for water supply from tanks 1 and 2 operated solenoid valves water 5 and 6 and the total controlled solenoid valve water 7. It is also marked: 8 – sensor for water pressure determination; 9 - pipeline for water supply to the nozzles of special design [13]; 10-11N - operated solenoid valves for water inlet nozzle; 12-13N-nozzles; 14-15N - sensors of nozzles serviceability; 16-17N - devices for determining of dust concentration, 18 - a source of air pressure; 19 – air duct; 20, 21 - controlled solenoid valves for feeding of compressed air; 22, 23 - sensors of upper and lower water levels in tanks 1 and 2 respectively; 24 - sensor, determining the compressed air in the air ducts and 25 - microprocessor control unit for dust suppression.
The value of N is used to denote a variable number of the equipment used in the control system installation for dust suppression.

The main problem, which is solved by this installation, is the increase of dust suppression efficiency by automatically feeding control positive and negative charged water in the detection amount of dust in the air, defined devices 16-17N. The cycle of the unit include:
- Irrigation of positive polarity by water;
- Blowing of feed line by air;
- Irrigation of negative polarity by water;
- Blowing of feed line by air.

Blowing of feed line is held to squeeze water out of it in the feeder pipeline.

The greatest action of installation reaches is under irrigation by ionized water of ionized air flows, which are are mixed at the outlet of the nozzle jet injectors, which spray a thin water is achieved by using their special design. Containers 1 and 2 with ionized water of different polarity are used to create pressure in the system required for normal operation of nozzles 12-13N.

Extrusion of ionized water from tanks 1 and 2 is fulfilled by air supplied from the air ducts 19 from high pressure air source 18. The task of operating modes and management of equipment installation is performed by microprocessor control unit 25 using electromagnetic pneumatic 20 and 21 and hydraulic valves 5-7 and control circuits and management of their condition and control of nozzles condition by sensors 14- 15N.

Industrial dust suppression is performed after determining the number of its air devices 16-17N. Depending on the amount of industrial dust according to a special algorithm there turned on the necessary amount of fuel injectors 12-13N. Amount of dust in the air is determined using dust measurement equipment of DUSTHUNTER C200 type of SICK AG, which supports two measuring principles: the transmittance and scattered light radiation, measured concentrations of dust in the air, but one may also use another type of device, for example, speed camera of Fastvideo-400 model. SICK DUSTHUNTER C200 are stable even at very low or very high concentrations of dust, with automatic test the null point and point of reference and support of the installation. This device measures the dust content (transmittance): 0 ... 200 mg / m^3 / 0 ... 10,000 and the measured dust content (ambient light): 0 ... 5 mg / m^3 / 0 ... 200 mg / m^3 . It has the ability to measure industrial dust to 8 pm, and operate at ambient temperature from - 25 °C to 60 °C.

The most significant factors determining the dust content in the air in the working area of the unit is the structure of the dust, and the location of installation devices 16- 17 N for determining the concentration of dust in relation to the impact on it of dust forming factors, direction and speed of industrial dust .

In microprocessor control unit 25 industrial dust dispersion calculated from data devices 16-17N and depending on its level it is automatically determined by the required amount of controlled solenoid valves 10-11N for supplying of ionized water through nozzles 12-13N with simultaneous switching of solenoid controlled valves of water 5 and 6 and total water controlled solenoid valve 7. This algorithm is fed by compressed air from the air source of high presure18 opening operated solenoid valves for blowing 20-21 of ionized water nozzles 12-13N by compressed air.

Dispersion of industrial dust, which characterizes the particle size of industrial dust, varies widely and depends on the properties of dust and deliberately rocks, grinding mechanism, airflow rate, which supports suspended dust, location of source that creates dust, etc. As it is shown in [9,10], it is known that the systems with gaseous dispersion medium, which include

industrial dust are extremely low resistance aggregated, due to the inertia of the dispersion medium. These systems have only kinetic stability and therefore cannot exist at high concentrations of the dispersed phase. Therefore an important factor of dust stability is the density of the dispersed phase.

The microprocessor unit 25 allows to solve the following tasks:

- Select and justify averages characterizing the dust to determine the desired pressure of ionized water in the line and compressed air pressure in air ducts;
- To perform calculations technically more accurate in order to determine the number of simultaneous turning on of the nozzles;
- To determine duration of dust irrigation by water, positive and negative polarity;
- To determine the time of blowing of feed line by compressed air;

To determine the distribution we may use Rosina - Rammer - Sperling formula:

$$R(x) = 100\exp(-bx^n) = 100\exp\left[-\left(\frac{x}{x_e}\right)^n\right],$$

where R (x) - total weight of yield particle size larger than x;

x_e - particle size at which the output of R = 100 / e = 36,8%,

b - constant characterizing the degree of grinding;

n – constant of uniformity;

e - base of natural logarithms.

Using the integral curve of size distribution of dust particles there was determined the number of nozzles 10-11N necessary for dust suppress arising from the open area, which is a source of dust, considering its total surface area. As a source of dust is of a cone shape, the total surface of a cone area of dust source is the sum of the square base of the cone and the lateral surface area: $S = \pi R2 + \pi R l = \pi R (R + l)$, where S - area, R - radius of the base of the cone, l - cone generating.

As can be seen from the graphs given in Figure 2 for the surface area of the cone in the open area of 100 m^2 maximum four nozzles are used, for plane surface size from 100 m^2 to 5000 m^2 - 8 nozzles and over 5,000 m^2 to 10,000 m^2 - 32 nozzles.

Software of microprocessor unit 25 control dust suppression is several modules, each of which performs specific functions:

• receiving and processing of information from the device measuring dust of DUSTHUNTER C200 type;

• calculation of spatial and temporal characteristics of industrial dust;

• calculation of dispersion of industrial dust and determination of distribution function of particles according to their size;

• formation of control actions on hardware setup for dust suppress;

• preservation and output of information about the air environment;

• ensuring dialogue with the operator (user interface).

All information about the installation work for dust suppress can be transmitted through the USB channel to dispatcher's computer, which can perform remote control of the system via the same channel if it is necessary.

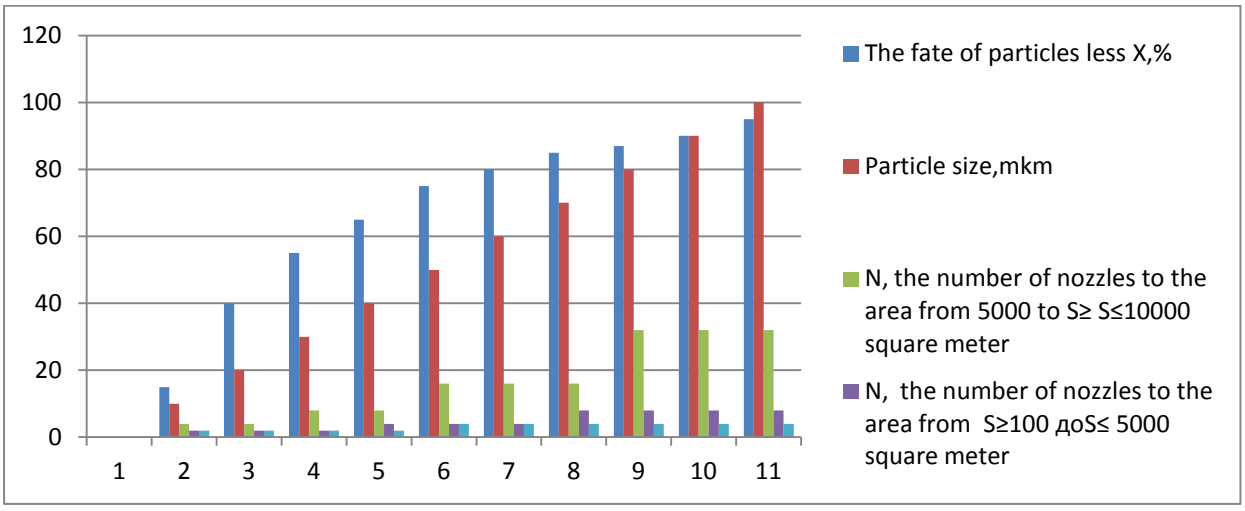

Figure 2. The integral distribution curve of particle size and a certain number of nozzles depending on the source plane surface dust, which has the shape of a cone and stored outdoors

Conclusions

1. To confirm the integral curve of particle size distribution and number of nozzles depending on the plane of open area with the source of industrial dust it is desirable to carry out industrial research of installation work to suppress dust with suggested automated control system.
2. As part of the installation for dust suppress instead of dust measuring device of DUSTHUNTER C200 type to use and carry out industrial research of speed camera model Fastvideo-400. The camera is made on the base of 10-bit color or monochrome CMOS – matrix of format 1/2 "with a resolution of 640 x 480 and progressive scan and allows you to record video signal at a frequency of 400 frames per second at full screen resolution. When reducing the number of lines and their length it is possible proportional increase in frequency of scanning: for the area size of 320 x 240 you can get up to 1500 frames per second, and for area 160 x 120 - up to 5600 frames per second. During high-speed video recording camera displays, data with speed up to 1240 Megabits per second and these data are transmitted in a continuous mode though Camera Link cable to a computer memory though frame grabber.

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