About the technological equipment tightness evaluation method in asbestos-cement products manufacturing

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Abstract. The technological equipment evaluation method as a dust emission source, adapted for the asbestos-cement production field is presented. An example of determining the process equipment tightness and calculating the dust emissions amount in the stocking plant workshop for the asbestos-cement products manufacturing is given. It made it possible to identify the sources of the highest dust emissions, to evaluate the quality of functioning of the used means of air purification of the working area, the harmful substances maximum permissible concentration excess level. The recommendations to reduce the negative impact of the dust factor in the enterprise working areas air are given.

Introduction

To determine the process equipment tightness degree, it is necessary to evaluate it as a dust emission source. The main factors are: the quality indicators identification, such as the dustiest sources, comparison of measurements with previous ones, their assessment in relation to general industry indicators. A conclusion on the tightness degree compliance with the standard indicators is made on the basis of the dust emissions values obtained from the equipment [1]. To achieve the greatest aspiration efficiency means that dust removal systems full examination technique can be used.

In the asbestos-cement products manufacturing, the following components and equipment should be aspirated: asbestos injection dispensers, conveyor runners, elevators, finished product bunker, dryer drum, belt conveyor, granulator drum, cargo belt conveyor [2]. The disadvantages in the organization and operation of technological systems, leading to significant dust loss due to insufficient sealing of equipment include:

- technological equipment is not completely aspirated;
- suction units are not equipped with aspiration funnels, therefore dust enters the aspiration system;
- unsatisfactory aerodynamic coordination of the systems individual sections;
- failure to comply with the uniformity of the dust-air flow speeds;
- significant differences in the aspirated air volume for equipment of the same type at different production sites;
- the systems individual sections clogging with dust, since the exhausted air speeds do not correspond to the dust properties;
- there is an incorrect air ducts diameters selection, which leads to the pipeline entire cross section clogging.
Technological Equipment Tightness Evaluation in the Asbestos-Cement Products Manufacturing

To ensure the satisfactory air conditions at workplaces, in addition to monitoring the chrysotile asbestos dust concentration, it is necessary to estimate the dust emissions amount from process equipment, the dust precipitation density, and the equipment tightness. For this purpose, a method for estimating the dust emission amount from process equipment and determining its tightness for enterprises producing products made of chrysotile asbestos and cement has been developed [3].

The authors have carried out the preparatory work. In this case, the determination of the main dusting sites arising during the process equipment operation was of particular importance. The process equipment analysis in the asbestos-cement plant procurement shop allowed to determine the main dust emission sources: asbestos unpacking sites, slate sawing machines, asbestos injection dispensers, elevators, conveyor runners.

Preliminary measurements of the dust, carried out according to standard methods [4], for each piece of technological equipment showed that the area in the working area near the transfer station runners is subjected to the greatest dust emission.

To calculate the air exchange amount and develop the effective measures to combat the harmful substances release, it is important to determine the amount of dust entering the working area air from the MTO process equipment.

In accordance with the methodology based on the M.P. Kalinushkin’s research, the dust mass coming from the dusting source, is calculated as the sum of the individual masses of dust deposited on different floor parts [5]:

\[
M_{mo} = \left( \overline{G}_1 F_1 + \overline{G}_2 F_2 + \overline{G}_3 F_3 + \ldots + \overline{G}_n F_n \right) = \sum_{i=1}^{n} \overline{G}_i F_i, \quad \text{kg/h},
\]

where \( \overline{G}_1, \overline{G}_2, \overline{G}_3, \ldots, \overline{G}_n \) – define the dusting density on each surface area; \( F_i \) – is the surface area of the subsidence, \( m^2 \); \( i = 1, \ldots, n \) – is the sediment dust surface areas number.

V.N. Azarov and E.I. Boguslavsky [6], proposed to determine the amount of dust dislodged from the process equipment in the following form:

\[
M_{mo} = \frac{n}{360} \sum_{i=1}^{n} \frac{\pi \varphi}{x_i} \overline{G}_{\max i} \left[ 2 \frac{x_i^2}{a_i^3} + \left( \frac{X_K}{a_i} + \frac{X_K - \Delta_i}{a_i^2} \right) + 2 \frac{a_i^3}{a_k^2} \right] \exp \left( -a_i x_i \right) ,
\]

where \( \varphi \) - is the pollutants area, hail; \( a \) - is a dust saturation indicator; \( X_K \) - is the segment from the measurement point of the dusting intensity to the source of dust emission, m; \( G_{\max} \) - is the sedimentation rate of dust particles directly at the source, g/(m²·h); \( \Delta \) - defines the interval between the first and dusting subsequent sources, m. The dust movement direction is crucial for calculating the intensity of dust settling on a horizontal surface. It can be determined by placing the trap plates every 2m from the polluting source in a circle. Such traps are prepared for the research in the laboratory. Their inner surface is covered with a thin layer of non-drying oils. They are weighed and numbered [7,8]. Next, the traps are placed at a distance from the dusting source along the circumference through an angle \( \pi/4 \). The traps layout is shown in Fig. 1. It is determined taking into account the specifics of a particular production. The dust settled in each plate is weighed, and the distribution intensity of dust settling is determined. The specific method makes it possible to determine the dislodged dust amount with engineering accuracy. In this case, the density of dust takes values from 0.1 to 100 g/(m²·h). When the results are obtained, it is necessary to determine the dusting density maximum and minimum values - \( G_{\min} \) and \( G_{\max} \), respectively. In order to find the centerline for the dusting area of a fixed source of dusting, they should be carried through the \( G_{\min} \) and \( G_{\max} \) values. The dust settling area is divided into sectors, namely, they get two sectors with the largest and smallest subsidence [9].
place at least three arcs. There are 3 traps on them. The duration of the experiment (τ) is 3 hours, the area of each plate (F) is 0.003768 m².

The experimentally obtained dust is weighed in order to determine the dust precipitation average density [10,11]:

\[ G_o = \frac{G}{F \cdot \tau}, \text{ kg/(m}^2\text{h)} \]  \hspace{1cm} (3)

where G is the dust mass caught by the plate, kg; F – is the plate area - traps, m²; τ -is dusting time, h.

The change in the dust density of \( G_o \) at a distance from the pollution source can be determined by:

\[ G_j = G_{max} \cdot e^{-ax}, \text{ kg/(m}^2\text{h)} \]  \hspace{1cm} (4)

where \( a \) is a parameter that takes into account air mobility and other parameters, 1 / m.

**Figure 1.** The layout of the plate traps: a - primary metering; b - main measurement

Using the equations and transformations system, we find the parameter \( a \) for polydisperse dust of asbestos cement. Take the distance \( j \) from the \( i \)-th source of dust emission \( j_1 = 1.5 \text{ m}, j_2 = 3 \text{ m}, j_3 = 4.5 \text{ m}, \) then

\[
\begin{align*}
    a_1 &= \frac{1}{3-1.5} \cdot \ln \frac{45.6}{12.3} = 0.87 \\
    a_2 &= \frac{1}{4.5-1.5} \cdot \ln \frac{45.6}{5.2} = 0.72 \\
    a_3 &= \frac{1}{4.5-3.0} \cdot \ln \frac{12.3}{5.2} = 0.57 \\
    a_{cp} &= \frac{0.87 + 0.72 + 0.57}{3} = 0.72
\end{align*}
\]

Thus, the dust settling density takes maximum values in the procurement workshop when influenced by two adjacent sources and is calculated according to the formula:

\[ G_{max} = \frac{134.3 + 106.7 + 132.8}{3} = 124.6, \text{ g/(m}^2\text{h)} \]  \hspace{1cm} (5)

To find the total amount of dust emission from the considered source sector, the determined parameters \( G_{max}, a, x_e \) and \( M_{no} \) are calculated. For asbestos overfilling unit \( M_{no} = 2.6 \text{ kg/h}. \) Dusting from a specific source of dusting can be found as a result of doubling the sum of the dust
sedimentation average indicators in the sectors with the highest and lowest dust loss [12,13].

Indicator $M_{cp}$ we calculate separately for each type of equipment. Let the number of a certain type equipment – $n_i$, then the total mass of dust from the production equipment $M_i$ can be determined:

$$M_i = \sum_{i=1}^{n_i} M_{cp} \cdot n_i$$

(6)

and the total dust mass due to incomplete equipment tightness:

$$M_T = \sum_{i=1}^{n_i} \sum_{k=1}^{k_i} M_{cp}$$

(7)

where $n$ is this type equipment units number; $k$ – is the dust emission types total sources number.

Since the amount of dust carried away by the ventilation and aspiration systems ($M_1$), and the amount of dust carried through the room openings ($M_2$), in equation (8) will be only 0.05-0.1 of the dust emission total amount to the workshop ($M$):

$$M = M_1 + M_2 + M_T$$

(8)

then the total mass of dust released into the work area is calculated as:

$$M_{mo} = 1.1 \sum_{i=1}^{n_i} \sum_{k=1}^{k_i} M_{cp}$$

(9)

and the power of dust emission from one material transfer unit will be:

$$M_{mo} = 1.1 \cdot M_T = 1.1 \cdot 2.6 = 2.86 \text{ g/h.}$$

The Chrysotile Asbestos Dust and Cement Aerodynamic Characteristics Research

Also, chrysotile asbestos and cement dust were studied to determine the particles aerodynamic characteristics by the method of fractional sedimentation, followed by analysis of its dispersion composition and plotting dependencies of the dust particles sedimentation rate on their equivalent diameter in a probabilistic-logarithmic grid [14].

As a result of the research it was revealed that within 17 seconds the settling particles’ diameter decreased. After 3 seconds the median dust diameter was 78 μm; after 5 seconds - 53 microns; after 7 seconds - 40 microns; after 9 seconds - 33 microns; after 11 seconds - 28 microns; after 13 seconds 24 microns, after 15 seconds - 15 microns; after 17 seconds - 9 microns. According to the measurement results, regularities of the change in the sedimentation rate from the equivalent particle diameter in the probabilistic-logarithmic grid (Figure 2) were obtained.

Figure 2. Dependence of the sedimentation rate on the equivalent diameter of a particle in a logarithmic grid: 1 — minimum equivalent diameters; 2 - median equivalent diameters; 3 - maximum equivalent diameters.
Summary
The results of estimating the chrysotile asbestos dust and cement amount from the process equipment and determining its tightness showed that the highest dust emission is observed after 0.5-1 m from the source and exceeds the maximum allowable concentration up to 7 times. The dust settling density takes the maximum values in the procurement workshops of asbestos-cement production with the influence of two adjacent sources and is equal to 124.6 g / (m2 · h). Dust generation capacity from one material transfer unit is 2.86 g / h.

According to the aerodynamic studies, chrysotile asbestos and cement particles have a maximum diameter of 78 microns, a median diameter of 57 microns, a minimum diameter of 7 microns at an air flow rate of 0.4 m / s; the maximum diameter is 26 μm, the median diameter is 22 μm and the minimum diameter is 4.5 μm at a speed of 0.1 m / s; the maximum diameter is 11 μm, the median diameter is 6 μm and the minimum diameter is 2 μm at a speed of 0.05 m / s. The dust settling average speed is 0.21 m / s; however, the recommended air velocity in the aspiration systems is: 4-5 m / s - for vertical sections located along the technological scheme to extruders; 9-11 m / s - after extruders, 14-15 m / s - for horizontal sections before extruders, and 16-18 m / s - after extruders. Thus, in order to reduce the dust content in the working area air in case of the equipment tightness sufficient degree, it is necessary to increase the local suction aspiration volume and the average sedimentation rate of chrysotile asbestos dust and cement. In case of the equipment tightness insufficient degree - to offer a pneumatic cleaning system.

To exclude possible dust loss from aspiration devices, they should create a minimum vacuum in the working volume (50 Pa for capacitive equipment, 100 Pa for transport). For local suction, the speed in the working space plane should not exceed 0.5 m / s to ensure its recommended aspiration funnels.

The results of the research allow to formulate a number of recommendations that will improve the aspiration systems efficiency as well as the sanitary and hygienic conditions in the workplace.

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