Development of machine for collection of cement dust

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Abstract. One of the negative changes in the Earth's ecosystem is air pollution from cement production waste. Cement industry enterprises annually emit more than 27 million tons of dust into the environment. They account for 2/3 of industrial emissions of solid substances and 44% of gaseous ones. The construction of various facilities is increasing every year. This leads to increased cement production and additional pollution. The most dangerous is fine dust (particle size less than 10 microns). It was found that a significant part of the fine dust is carried away by the exhaust gases even before entering the stage of dry cement formation. It is deposited in various production facilities. Further dust can enter the atmosphere from the workshops and cause pollution. Collecting it is a very complicated and expensive process. In the article, the design of a machine for collecting and unloading cement dust makes it possible to collect about 69% of all dust in the workshop and on the territory of the plant and load it into a special container. This significantly improves the ecological state of the air.

1 Introduction

Dust is one of the negative factors that have a great impact on the human condition [1-3]. Moreover, the dust appears in various forms. In an urban environment, the level of dust is especially high [3-10]. In contrast to rural areas, the size of dust particles in the city is much smaller and more of them [5-7, 10-14]. This creates the greatest danger to humans and living organisms.

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In large cities, air pollution from cement production wastes is a particular danger. Cement is the most important element during construction [5-7, 10, 15-19]. Cement industry enterprises annually emit more than 27 million tons of dust into the environment. They account for 2/3 of industrial emissions of solid substances and 44% of gaseous ones. The construction of various facilities is increasing every year. This leads to increased cement production and additional pollution. Cement production includes two stages: the first is the production of clinker, the second is to bring the clinker to a powdery state with the addition of gypsum or other additives. The first stage is the most expensive, it accounts for 70% of the cost of cement. The content of dust fraction less than 10 microns as the material passes through the technological process of processing increases from 10.75 to 75%. Fine dust is formed during the roasting of raw materials in dry rotary kilns. This dust is so fine that a significant part of it is again carried away by the exhaust gases even before it enters the dry cement stage. This dust must be removed from workshops, warehouses, etc.

In dry weather, dust is transported over long distances across the metropolis. From the metropolis, the dust can be transferred to agricultural fields. This will change their state [11-14]. When there are strong gusts of wind and no trees, the dust gets through the Windows and doors to the premises and settles there. In such confined spaces, it becomes difficult for people to breathe [1-3]. Various optical methods and devices based on them are used to control the dust concentration [20-26]. It should be noted that all measurements must be performed in Express mode for operational control of dustiness of premises [27-32]. In some cases, radar methods are used to control dust on the territory [33-36].

A large number of methods and machines have been developed for dust removal. The most effective machines are those that collect dust in a special container. This dust can then be used as an additive to the raw material mass in the manufacture of silicate bricks, as fertilizers for liming acidic soils in agriculture, etc. Therefore, the development of new and modernizing such machines is an urgent task. Since this allows in addition to reducing the environmental burden on the ecosystem to provide affordable raw materials for various industries and agriculture.

2 Machine design and how it works

In fig. 1 shows the appearance of the machine developed by us for collecting dust in the workshops and on the territory of the enterprise.

![Fig. 1. Picture of a dust collector placed on a mobile system.](image)
The centrifugal fan sucks dust into the cyclone separator through the inlet hose and a special impeller opening. In a cyclone separator, cement dust rotates at a centrifugal speed. Under the influence of gravity, it settles into the airlock. The motion of particles in the outer vortex of a cyclone can be determined by Newton's laws of motion as follows:

$$\sum F = m_p \frac{dV_p}{dt}$$  \hspace{1cm} (1)

where $m_p$ – mass of a particle of a certain size, $v_p$ – particle speed of a certain size.

A new solution is proposed in the machine design. Filtered air is returned to the impeller blade to increase the pressure again. This allows you to blow the dust and airlock into a pipe, which sends the dust to a special container.

The design of the cyclone separator and the appearance of the centrifugal fan are presented in fig. 2.

![Fig. 2 (a, b)]. Principle of operation of the cyclone separator (a) and appearance of the centrifugal fan (b).

The fan uses radial blades, as they are best suited for dust or air. This design of blades is less susceptible to clogging, erosion and destruction and has self-cleaning properties. The following optimal operating parameters were calculated for the fan. Static suction pressure equals -196.4 N/m². The static feed pressure is equal to 784.8 N/m². The gradient of the static pressure $\Delta P_s = 981.2$ Pa. Speed of rotation of the impeller $N = 1600$ rad/min.

### 3 Results and Discussion

Most enterprises use electrostatic precipitators in their dust collection systems. They provide a purification rate of 95-98%. The dust level is about 300 mg/m³ on the order of the dust at the outlet. At large enterprises with a large production volume, the latest models of electrostatic precipitators are installed. These filters are very expensive equipment and require high maintenance costs to ensure stable operation [37–39]. The use of these filters...
can reduce residual dust content to a level of 50-100 mg/m$^3$. With large production volumes, the concentration of dust in the workshop reaches the same limits as with small production. At a cement plant, the concentration of dust particles was measured using a CEM DT-9680 air dust counter. Residual dust content was monitored for two hours. During this time, the dust was not removed. In fig. 3 shows the results of measuring the level of dust in the room and on the territory without dust cleaning and when cleaning every hour.

![Fig. 3. Dependence of the level of dust in the room. Schedule 1 corresponds to the absence of dust collection, schedule 2 - cleaning every hour.](image)

The results obtained show the efficiency of the developed cement dust collection machine. With a residual dust content of about 50 mg/m$^3$, the cleaning schedule allows you to ensure the necessary sanitary standards in the workshop (no more than 200 mg/m$^3$). When the level of dust increases, it is necessary to carry out cleaning constantly and preferably using several machines. Particular attention must be paid to collecting dust after stopping work (cement production).

To justify the development, the overall performance of the machine for collecting cement dust of various sizes was evaluated. In table 1 are presented one options for assessing this effectiveness.

**Table 1.** The effectiveness of work of the machine for collecting cement dust

| J | Size range (µm) | $d_{pj}$ ($\mu$m) | $\frac{d_{pj}}{d_{pc}}$ | $n_j$ | $\frac{n_j}{M_j}$ (%) | $\frac{m_j}{M_i}$ (%) |
|---|-----------------|-------------------|-------------------------|-------|------------------------|---------------------|
| 1 | 0-2             | 1                 | 0.361                   | 0.115 | 1.0                    | 0.12                |
| 2 | 2-4             | 3                 | 1.083                   | 0.539 | 30.0                   | 16.17               |
| 3 | 4-6             | 5                 | 1.805                   | 0.765 | 30.0                   | 22.95               |
| 4 | 6-10            | 8                 | 2.888                   | 0.893 | 14.0                   | 12.5                |
| 5 | 10-18           | 14                | 5.034                   | 0.962 | 10.0                   | 9.62                |
| 6 | 18-30           | 24                | 8.064                   | 0.987 | 5.0                    | 4.94                |
| 7 | 30-50           | 40                | 14.44                   | 0.995 | 1.0                    | 1.0                 |
| 8 | 50-100          | 75                | 27.07                   | 0.999 | 1.0                    | 1.0                 |

68.3%
Calculations performed using the results of measuring the concentration of particles of various sizes (data on concentrations were obtained using an optical air density meter) showed that the machine allows collecting about 69% of cement dust settled on various surfaces.

4 Conclusion

The results show the need to continue working to improve the efficiency of collecting cement dust developed by the machine design. In previously used machines, the dust collection efficiency was less than 65%.

In addition, the productivity of the machine has increased. Under various contamination conditions, the machine can collect up to 100 kg of cement in an hour. This result shows that the process of cleaning the territory also allows you to partially compensate for the cost of equipment maintenance. At the same time, sanitary standards are provided for the work of people in the room. The collected cement dust is effectively used in construction and agriculture [39-41].

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