Improvement of dedusting efficiency of technological equipment for manufacturing of coloured calcium silicate bricks

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Abstract. The key factors for obtaining coloured calcium silicate bricks is the high degree of dispersion and precise dosage of the colouring matter, as well as its uniform distribution in the silicate mixture. Dust particles of a colour pigment pose the most harmful effect on the health of workers at the industrial shop. In the course of components mixing, a large amount of dust from sand, lime and pigment is released into the working zone air since the process of components mixing implies materials pouring while proportioning as well as vigorous mechanical mixing. For the purpose of the quantitative and qualitative analysis of the working zone air contamination in a components mixing shops, it is necessary to investigate the dust conditions at the shop, the particle size distribution of the mixture components, the concentration of hazardous substances in the working zone air, the aerodynamic properties of dust.

In order to choose dedusting measures for a components mixing shop of a manufacturer of coloured calcium silicate bricks, the authors have carried out the particle size distribution analysis of the dust sampled from the working zone air as well as the measurements and calculations for the analysis of the regularities of dust dispersion and settling in the working zone air.

The mixture components are charged into the supply bin of the mixing machine in a continuous mode, therefore intensive dust emissions occur in the upper part of the supply bin accompanied by the slippage of dust particles through untight joints. The evaluation of the dust emission into the working zone air was carried out according to the technique given in the work [1]. Inside the shop, the dust is caught by the air flows and spread around the whole indoor space due to the occurrence of vortex flows causing dust particles to stay in suspended state, hence the air in the shop is polluted. In order to evaluate the amount of dust particles in the working zone, it is important to know their aerodynamic properties [2,3]. The main reasons for increased dust generation are the absence of isolating devices located at the place of intensive dust generation and their substandard performance.

Based on the field measurements, the solutions aimed at improving the dedusting efficiency of technological equipment have been developed. The approaches previously described in the paper [4] are used in the present work. An isolating device for dust separation has been suggested, which is imbedded into the supply bin of the mixing machine and applies a counter-current swirling flows apparatus.
A specific feature of a dust collector with the counter-current swirling flows (CSF) is that the air is delivered into it in two different flows through the lower and upper inlets, which enhances the efficiency of the apparatus performance [5,6,7].

In order to conduct proof tests of the isolating device for dust separation, a laboratory unit was installed the scheme of which is given in figure 1.

![Figure 1](image1.png)

**Figure 1.** Scheme of dedusting unit: 1- dust separation device; 2- transporters; 3- loose material; 4- supply bin of the mixing machine; 5- mixing machine; 6- fan system; 7 – the upper inlet into the CSF apparatus; 8 – the lower inlet into the CSF apparatus; 9- CSF apparatus.

For the purpose of improving the dust conditions in the working zone air of a components mixing shop, the authors have developed a dedusting device imbedded into the supply bin. The suggested device is intended for the enhancement of the efficiency of dust emissions removal inside the mixing machine in order to avoid slippage and hence the dust occurrence in the working zone air. The scheme of the dust separation device is given in figure 2.

![Figure 2](image2.png)

**Figure 2.** Dedusting device in the supply bin of the mixing machine: 1 – the case of the supply bin of the mixing machine; 2- supply bin cover; 3- charging inlet; 4- mixing branch duct; 5,6 – air ducts for mixture charging; 7 – vent gaps; 8,9,10 – tangential branch ducts; 11- cylindrical branch ducts, 12,13,14-sections with varying diameters; 15- exhaust ventilation duct; 16 – the outlet for mixture dumping into the mixing machine.
The case of the supply bin has ventilation gaps at the opposite sides in the upper part under the upper cover, which are connected through air-tight tangential branch ducts and two cylindrical branch ducts designed with sections of varying diameters with their ratio of 1:1.4:1.7 with respect to the smallest diameter, with an exhaust ventilation duct connected to the exhaust ventilation fan.

The laboratory unit of the dedusting device in the supply bin is shown in figure 3.

The advantage of the suggested device is that the tangential branch ducts 8,9,10 create an intensive swirling of the air flow with dust, thus increasing the injection capacity and intensive turbulent air exchange, which allows avoiding dust deposits formation at rather high concentrations of dust-like materials [8,9]. The tangential branch ducts – the flow swirlers – are demonstrated in figure 4.

To summarize the results of the preliminary experiments, the intervals of the factor varying and the area of experimenting were chosen, which are presented in table 1.

Table 1. Coding of the factors within the investigation of the process of dust collection in the dust separation device.

| Name of the factor                                      | Levels | Δx_i |
|--------------------------------------------------------|--------|------|
| Relative air rate for removal \( \dot{L} \), m\(^3\)/s   | -1     | 0    | +1   | 0,05 |
| Median particle diameter \( d_{50} \) of the mixture charged into the supply bin, \( \mu m \) | 4,0    | 12,0 | 20   | 8,0  |
| Relative rate of the supplied                          | 6      | 8    | 10   | 2,0  |
The power series, more accurately, a part of them – algebraic polynomials – were chosen for the statistical model of the process [25, 39, 46]. To determine the value, fewer tests are required for polynomials of a lower degree, therefore the polynomial of the following form was taken as the statistical model of the process:

$$Y = b_0 + \sum_{i=1}^{3} b_i x_i + \sum_{i<j} b_{ij} x_i x_j + \sum_{i<j<l} b_{ijl} x_i x_j x_l$$  \hspace{1cm} (1)

The planning matrix was chosen for the design of a full factorial experiment of $3^3$ type [25, 39]. In this case, a series of 2 tests was carried out at each combination of the levels of the experiment.

Comparing the confidence intervals with the value of the obtained absolute coefficients and evaluating the significance of the coefficients, the authors obtained the following regression equation:

$$\eta_{yada} = 1.835 + 0.0525 \cdot x_1 - 0.435 \cdot x_2 - 0.1375 \cdot x_3 + 0.09 \cdot x_1 \cdot x_3$$  \hspace{1cm} (2)

The obtained equation are the mathematical model of the studied process of dust collection past the dust separation device in a CSF apparatus. The code values of the factors $x_1$, $x_2$ and $x_3$ are coupled with their natural values ($\overline{L}$, $d_{50}$, $\overline{G}$) through the following relations:

- $x_1 = (\overline{L} - 0.61)/0.05$
- $x_2 = (d_{50} - 12)/8.0$
- $x_3 = (\overline{G} - 8.0)/2.0$  \hspace{1cm} (3)

These equations will be valid only for the following values of the independent variables:

- $\overline{L} = 0.56 \div 0.66$ m$^3$/s
- $d_{50} = 4.0 \div 20$ μm
- $\overline{G} = 6.0 \div 10.0$ l/h

The reproducibility of the tests was verified according to Cochran's criterion, the significance of the coefficients was checked through Student's $t$-test, and the mathematical model adequacy was assessed through Fisher's criterion.

The obtained results show that the equations are adequate for the preset significance levels, which is substantiated by the assumed mathematical model of the conducted investigation into the process of air flow treatment for dust removal ($d_{50} = 4.0 \div 20$ μm) in a CSF apparatus. Thus, an aspiration system applying a dedusting device and a CSF apparatus for the supply bin of the mixing machine has been designed for the manufacturing of coloured calcium silicate bricks. Experimental investigations have been carried out and the functional dependence of the dust collection efficiency of a CSF apparatus on the independent factors such as the air removal rate, the particle diameter in the mixture charged into the supply bin and the supplied materials rate has been determined. In addition, the theoretical suppositions taken as the basis for the design of a multifactorial experiment have been substantiated by the mathematical model. Therefore, the regression equation allows determining the optimized conditions of the dust collection process through variable factors variation.

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