Designing energy-efficient aspiration hoods used for protection during reloading of moldings compounds at casting shops of machine-building enterprises

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Annotation Currently, aspiration hoods consume up to 20% of total circulating assets of an enterprise. The article presents an innovative approach to the design of aspiration hoods for reloading bulk materials by the example of molding compounds of casting shops. This approach includes the design of aspiration hood according to required parameters. This technique will allow receding from the conventional energy-consuming two-step scheme of air cleaning, simultaneously reducing the expenditures and augmenting the reliability of the systems. The suggested approach will enable designing the hoods that reduce the energy-consumption of aspiration systems more than seven times.

1. Introduction

Technological processes in many industrial branches, including casting shops at machine-building enterprises, are connected with transportation and processing of bulk material, for instance, molding compounds (grinding, loading, unloading, mixing, etc.).

These processes usually include gravitation transportation of large amounts of bulk materials in closed chutes, which is accompanied by intense dust liberation. The increased concentration of dust both in the working area and in the atmosphere causes various human diseases and environmental pollution. All these factors reduce the performance and investment potential of an enterprise. According to analysis [1], all dedusting systems consume up to 20% of total circulation assets of an enterprise.

The given analysis of the material processing in [2] allows concluding that the largest dusting is connected with loading and unloading operations involving belt conveyors. The most suitable way of dedusting in this case is localization of dust liberation with the help of local exhaust ventilation, i.e. aspiration.

As a rule, the aspiration systems feature two-step air cleaning: a cyclone - for separating from coarse particles, and a fine filter. This system is pretty energy-consuming and requires considerable operation expenditures. In this connection, one-step air cleaning is the most preferable option.

According to research [3] — including that performed at Energomash JSC (Belgorod) and JSC Mtsensk foundry — the technology of casting plant usually features small heights of conveyor-to-conveyor material reloading (less than 2–4 meters). This conditions a relatively small required aspiration volume, hence small aspiration air rates. These reloading height values are typical for all foundries, which is determined by the technology of molding compound processing. There are a lot of various designs of hoods intended for the reduction of dust concentration [4, 5]. However, the majority of them are very complex, hard to operate and have low reliability due to the presence of movable parts and mechanisms. These conditions induce the implementation of advanced aspiration hoods having a simple structure that will both act as a device for localizing the dust liberation source and as the first air cleaning stage eliminating the need in one of the air cleaning systems. This will reduce the energy-consumption of the aspiration system. The research works [2, 3, 6] have shown that the effective work of the hoods is only possible if their design considers the dynamics of dust flow formation and evolution.

According to the results of previous studies [1], the implementation of improved hoods allows reducing the energy consumption of aspiration systems more than seven-fold.

In this connection, the development of new schemes, engineering techniques and methods for their calculation and design is a very urgent problem.

2. Results and Discussion

The authors have made the analysis of existing works and hood schemes [1, 2], which has demonstrated that a promising direction in their development is the use of the concept featuring double-walls with a rigid divider. This hood type has a range of strong sides, in particular, decreased dust concentration at the output for a small required aspiration volume and a simple scheme. The decrease in the required volume of aspirated air by such hood design results from more uniform depression along its external walls. The reduction of concentration is due to the inertial forces affecting the dust particles flowing around the divider. For instance, this hood scheme was used to make enhanced design with double walls and a divider. Owing to the different inclination angle, an addition vortex is generated that intensifies the dedusting process (Fig. 1).

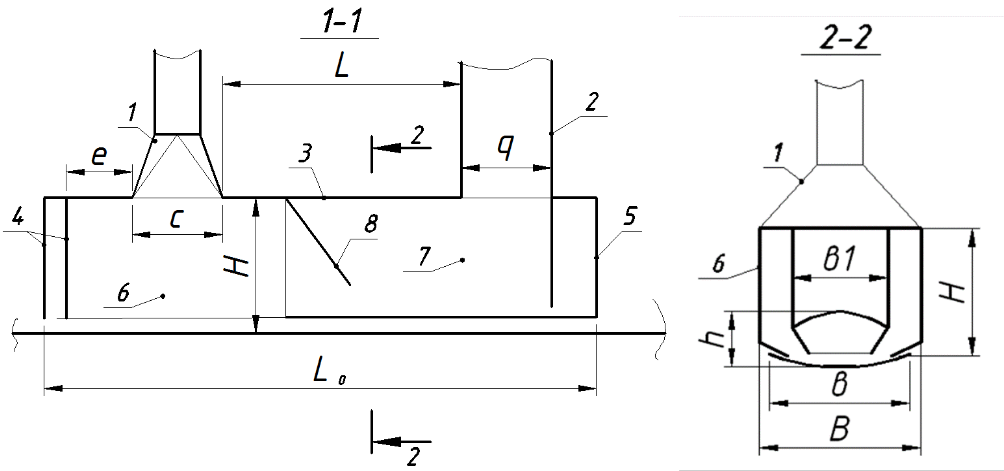

Figure 1. Hood with double walls and internal divider. 1 − suction bell; 2 − reloading chute; 3 − hood upper cap; 4 − apron; 5 − back wall; 6 − external side wall; 7 − internal side wall; 8 – inclined rigid divider.

The usage of such hoods as the first air cleaning stage requires and engineering technique of their design. In such case, the designing engineer having initial parameters that include material flow rate, reloading geometry, required parameters of dusted air at the hood output will be able to design the aspiration hood that will comply with all requirements. This means that the design of aspiration systems will involve avcompletely new innovative approach that is different in the very design of the aspiration hood as a typical device for air cleaning. Such design will be aimed at the determination of the geometrical parameters of the hood to ensure its demanded air cleaning level.

Below there is a brief review of the stages elaborated by us that are needed to design the dedusting aspiration hood with a due account for existing techniques [7].

1) Choose the types of aspiration hood. The most preferable is the hood with double walls and inclined rigid divider.

2) Set the initial parameters for consequent calculations: rate of aspirated air flow (aspiration rate) Q_a, leakage airflow Q_n, required dust concentration at hood output $A_{tr.}$.

3) By defining the average airflow rate at suction bell input U_{vh}, which depends on the type of reloaded material; determine maximum dust concentration A_{tr}, mg/m^3:

$$A_{\max} = \frac{A_{tr}}{72,2 \cdot 10^{-3} \cdot a_{per} \cdot U_{vh} \cdot \exp(-c)},$$

where

$$c = d + f\ ,$$

$$в = 3,75 - 0,33 \cdot \rho \cdot 10^{-3},$$

$$d = 0,63 \cdot \rho \cdot 10^{-3} + \left(0,62 + 0,022 \cdot \rho \cdot 10^{-3}\right) W\ ,$$

$$f = 0,03\left(W - 5 + 0,7\left(\rho \cdot 10^{-3} - 1,4\right)^2\right),$$

a_{per} is the coefficient in the effect of the inclined divider on the dust concentration according to authors' studies, including [1] a_{per}=0.32 at h/H=0.3;

Q_a is the aspirated air flow, m^3/s;

W is the humidity of the material, %;

ρ is the true density of the reloaded material, kg/m^3**.**

4) Determine the percentage of particles with the diameter of less than d_{max} in the reloaded material:

$$a = \frac{Q_a \cdot A_{\max}}{36 \cdot 10^6 \cdot G},$$

where G is the material reloading rate, kg/s.

5) Determine the maximum required diameter of dust aspirated by suction bell $d_{max.\ tr.}$:

$$d_{\max.\mathrm{tr}} = \frac{a \cdot d_1}{m_1 \cdot k_{per} \cdot 10^{-6}}$$

where d_1 is the average diameter of the smallest fraction, m;

k_{per} is the coefficient in the effect of the inclined divider on the inertial dedusting in the hood, k_{per}= 0.55 for divider h/H=0.3, and an inclination angle of 55º;

m_1 is the mass fraction of the smallest fraction, %.

6) Using parameter $d_{max.\ tr}$, determine the required geometrical parameters of the hood.

Using the dependence of the maximum dust diameter aspirated by the suction bell, determine the length of suction bell c:

$$\frac{Q_a}{B \cdot c} = \frac{d^2_{\max.\mathrm{tr}}}{5780} \rho \left(1 + 0,08 \frac{\frac{Q_a}{B \cdot c} L}{U_0 H}\right),$$

where

Q_a is ejected air flow, m^3/s;

Q_n is leakage air flow, m^3/s;

L is the distance between the chute and the suction bell, m;

H is the height of the aspiration hood, m (Figure 1.10);

U_0 is the average air flow inside the hood, $U_0 = \dfrac{Q_g + 0,5 \cdot Q_n}{b_1 \cdot h}$ m/s;

B is the width of the aspiration hood, m;

ρ is the true density of a dust particle, kg/m^3;

$U_{вх}$ is the air flow at the input of the suction bell, m/s. Let us determine the rest of geometrical parameters of the hood. For the aspiration hoods with single and double walls, the following optimal dimensions were experimentally determined [6] that are dependent on the width of conveyor belt *b* (Fig. 1):

- height H=0.75·b;
- distance between the chute and suction bell L=1.2·b;
- width B=1.2·b;
- distance between internal walls b_1=0.75·B.
- parameter L=1.2·b that determines the total length of the aspiration hood;
- distance between the front wall and aspiration hood c=1.4/e.

It should be noted that the inconsistency with a single parameter mentioned above will change the trajectories of air-dust flows in the hood, which will reduce its dedusting efficacy.

3. Conclusions

The analysis of aspiration hood used for processing of bulk materials has proven their applicability both as dust localization equipment and as the first stage of aspiration air cleaners. However, the existing calculations methods not always ensured the required cleaning of air in a hood. In this article, the authors suggested an innovative approach to the design of industrial aspiration systems that allows designing hoods with required parameters.

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