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DEVELOPMENT AND SUBSTANTIATION OF LAYOUT OF DUST EMISSIONS PURIFICATION SYSTEMS USED AT MOBILE ASPHALT PLANTS

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ABSTRACT

This paper describes properties of dust particles emitted in the course of asphalt plants operation, and analyzes design of various type dust collection systems used for dust emission purification. Two layouts of the dust systems including dust collectors operating with application of swirling flow and with application of centrifugal dust concentrators are proposed. A comparative analysis of both schemes efficiency is carried out.

Keywords: purification of dust emissions, swirling flow dust collector, layout of dust-collecting units, trapping of fine dust, centrifugal dust concentrator.

INTRODUCTION

Dust particles contained in the emissions of asphalt mixing equipments of asphalt concrete plants are characterized by a fine size (d_{50} = 36...78 μ), as well as by high suspension velocity (V_{whir} = 5.8 to...7.3 m/s) [1]. Data given in this paper which characterizes relation of mass and aerodynamic characteristics, as well as a relatively low adhesion ability preventing process of trapped particles enlargement due to adhesion and formation of coagulants, draws to conclusion that use of common inertial dust collectors in these conditions does not provide required values of dust emission purification degree.

A comparatively low adhesion ability of dust particles, and also the dust fine-dispersed structure, are factors contributed to use filtration purification methods, in particular, fabric bag filters. However, use of filtration methods is limited by high concentrations of dust particles (C = 1980...2160 mg/m^3). Relatively high concentrations make filtration methods economically unprofitable due to increased clogging and wear of the filter material and need for frequent shaking. Also, due to strict mass-dimensional restrictions to the equipment of movable and mobile installations, use of bag filters is difficult. In addition, due to the high aerodynamic resistance, it is difficult to use them as the main dust-collecting equipment in the systems for purification of movable and mobile asphalt mixing plants emissions because of need for powerful draft devices.

A two-stage layout with use of inertial dust collector for the first-stage can unload the filter elements and solve the problem of fine dust particles trapping. However, mass-dimensional characteristics of two-stage systems seriously complicate transportation and installation of their elements, and also, there is a problem of high energy consumption. The above factors cause relatively high capital, operating and depreciation costs, which, along with operational difficulties, make use of two-stage systems irrational.

MATERIALS AND METHODS

According to complex of mass-dimensional characteristics, purification quality, simplicity, reliability and economic efficiency, the closest to the requirements are dust collectors based on swirling flows, which possess such main advantages of inertial dust collectors of cyclone type as simplicity of design and operation, reliability and low cost, and also, they are characterized by significantly higher values of total and fractional efficiency [2-5].

It should be noted that, at the same time, relatively higher efficiency of fine particle separation does not always provide necessary degree of purification because swirling flows dust collectors, despite more efficient design, are still based on the principles of inertial separation. Since movable and, especially, mobile asphalt plants can work in close proximity to residential area, or in rare cases in residence territory, more severe requirements on the quality of dust emission purification, and especially on the degree of small dust fractions trapping, are imposed on purification systems included in asphalt mixing plants structure.

One of possible solutions to increase fractional efficiency of dust collectors by means of use of swirling flows is supply of different concentration dust flows to the primary and secondary inputs [6 -10].

To purify the flow fed to the secondary input of the dust collector by means of swirling flows, bag filters are proposed.

Given that the secondary input receives only part of total flow of gas-dust mixture delivered for purification, it is possible to use a filter with smaller performance than in the case of two-stage layout and this reduces aerodynamic resistance, as well as weight, dimensions and, as a consequence, cost of the dust purification equipment.

To improve a fractional efficiency of the unit, as well as to reduce a filter element load in order to increase the service life and operating costs, it is desirable to organize the gas-dust flows distribution so that fine

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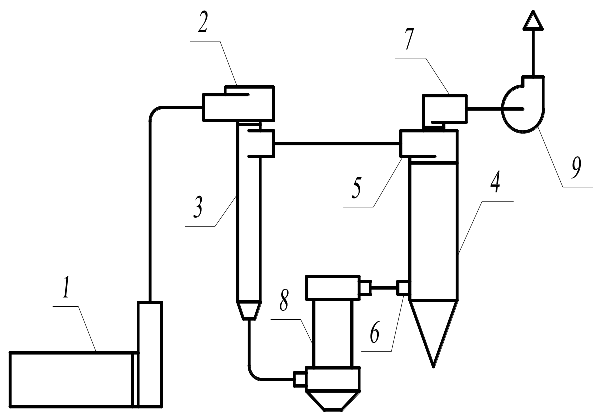
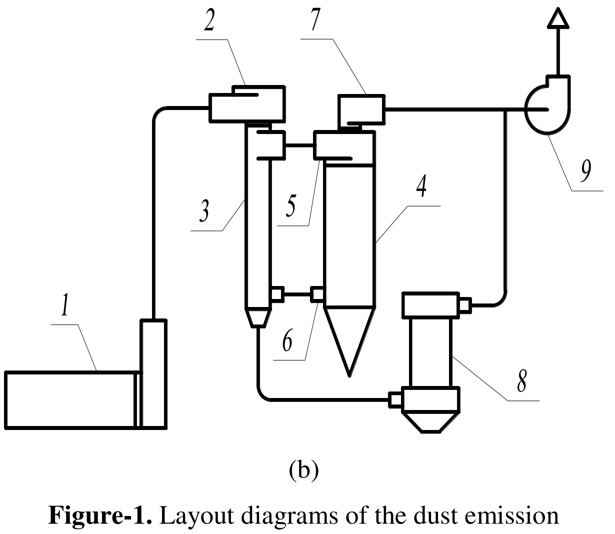
particles with a small concentration were delivered for filtration, and large particles with a high concentration – to the primary input of the VZP dust collector, respectively. To provide the required flow distribution, it is proposed to include into the layout a centrifugal dust concentrator [8, 10 - 12]. The primary flow leaving centrifugal dust concentrator will contain the largest particles which are separated under the action of centrifugal forces, the fine particles which were not trapped in the course of inertial separation are delivered to secondary flow fed to the filter.

Figure-1 shows two proposed layout diagrams of dust emission purification systems for movable and mobile asphalt mixing plants which use dust collectors based on swirling flows, separation of primary and secondary flows by means of centrifugal dust concentrators and following purification of the secondary flow with bag filters.



(a)



(b)

Figure-1. Layout diagrams of the dust emission purification system: 1 - drying drum of the asphalt mixing plant; 2 - scroll swirler of the centrifugal dust collector; 3 - cylindrical separation chamber of the centrifugal dust concentrator; 4-swirling flow dust collector; 5-primary input of the dust collector; 6-secondary input of the dust collector; 7 - flow unswirler; 8-bag filter; 9 - draft device.

Equipment according to the scheme shown in Figure-1 (a) operates as follows: dusty gases leaving the drying drum of the asphalt mixing plant (1) are fed to the tangential input of a scroll swirler (2) of centrifugal dust concentrator (3) in which the process of centrifugal separation of solid dust particles takes place. Due to prevailing of inertial forces over aerodynamic, larger particles leave separation chamber of the centrifugal dust concentrator (3) through the tangential pipe branch and are fed to the primary input (5) of the swirling flow dust collector (4). Flow containing fine dust particles which were not separated earlier continues to move in the axial direction of the separation chamber of the centrifugal dust concentrator (3), and then is fed to the inlet of the bag filter (8). The purified flow is transferred from the filter (8) to the secondary inlet pipe (6) of the swirling flow dust collector (4), where it is purified further. Under the influence of vacuum created by the fan (9), the flow is discharged through the chimney (conditionally not shown).

When consider complexity of the system layout, as well as presence of large number of swirling elements, it is important to reduce aerodynamic resistance as the increased values of the resistance are the cause for energy efficiency reducing and operating costs increasing. Instead of standard ventilation outlet, a tangential flow unswirler is installed at the outlet of the dust collector to recover residual energy of the swirling flow which was purified in the separation chamber of the swirling flow dust collector. Use of the unswirler reduces aerodynamic losses due to reuse of kinetic rotation energy of the flow. Also, pipes connecting the separation chamber of the centrifugal dust concentrator with primary and secondary (diagram b) pipe branches of swirling flow dust collector which allows recycling of the swirling flow energy in dust concentrator are designed as tangential.

Principle of operation of the equipment shown in layout diagram in Figure-1 b), consists in the presence of two parallel branches to which a low-concentrated flow passed through the centrifugal dust concentrator (3) is divided. To reduce aerodynamic resistance, a part of the low-concentration flow is transferred to the secondary pipe branch (6) of the swirling flow dust collector (4) through the tangential pipe branch. The other part is transferred to the bag filter (8) for purification, after which it is exhausted through the exit.

Use of the layout scheme " b " allows reducing of size and weight of the bag filter by reducing flow of gas delivered for treatment, and in addition, reducing of aerodynamic resistance of the system. At that, it is obvious that the system designed according to "a" scheme will have higher overall purification efficiency since the secondary input of the swirling flow dust collector receives a smaller number of fine particles trapped in the filter element of the bag filter (8). At that, fractional efficiency of the swirling flow dust collector which causes the largest effect on the total purification efficiency due to largest purified flow of the dust-gas mixture increases due to absence of breakthrough of fine particles from the secondary swirled flow into the outlet pipe.

Difference in the total efficiency will depend on a number of factors, including ratio of dust particles

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concentrations after the flows separation in the centrifugal dust concentrator, ratio of purified gas flow passing through the various parts of the system, efficiency of purification with bag filter and swirling flow dust collector, etc.

RESULTS AND DISCUSSIONS

The following parameters were used as basic data for comparative analysis: η_{VZP} – trapping efficiency of swirling flow dust collector that is a function of a portion of flow fed to the secondary input and ratio of dust particles concentrations in the flows fed to the primary and secondary inputs $\eta_{VZP} = f(L_2/L_{com}, C_2/C_1)$; η_f – efficiency of SMC bag filter according to catalogue data based on concentration and particle size distribution for dust particles contained in the gases fed for purification; η_{conc} – efficiency of flow separation by centrifugal dust concentrator characterized by ratio of dust concentrations in the secondary and primary flows $\eta_{conc} = 1 - C_2/C_1$.

Figure-2 shows a scheme for the dust emission purification system analysis made according to the scheme with a parallel bag filter (the second version of the layout). The total purification efficiency for the proposed layout scheme is evaluated based on the solution of a balance equations system characterizing mass of dust particles and compiled in accordance with calculation scheme shown in Figure-2.

Where

G_{com} = mass flow rate of dust entering the purification system;

G_1 = mass flow rate of dust entering the primary input of the VZP dust collector;

G_2 = mass flow rate of dust entering the secondary input of the VZP dust collector;

G_3 = mass flow rate of dust entering the bag filter for purification;

G_4 = mass flow rate of dust at the outlet of the VZP dust collector;

G_5 = mass flow rate of dust at the filter exit;

G_6 = mass flow rate of dust at the system exit;

K = a portion of purified gas flow transferred for purification in the bag filter;

η_{conc} =efficiency of flow division in dust concentrator;

η_{VZP} = efficiency of dust collector;

η_f = efficiency of bag filter.

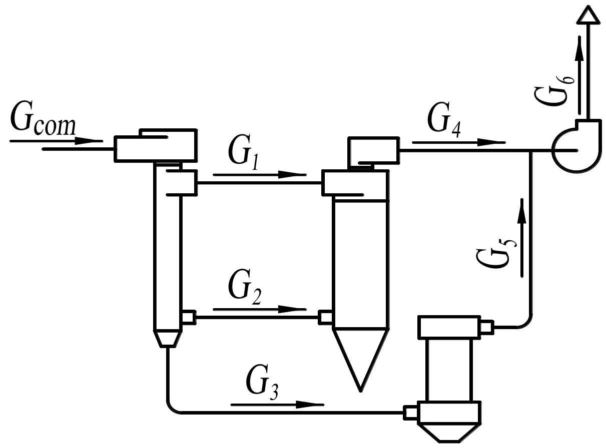

Figure-2. A scheme for calculations of the dust emission purification system made according to diagram with parallel bag filter.

The equation (1) can be transformed to a dimensionless form by dividing the equation by amount of dust transferred for purification from the drying drum

$$\left(\begin{array}{l} \overline{G_1} + \overline{G_2} + \overline{G_3} = 1 \\ \eta_{conc} \overline{G_1} = 1 \\ G_3 = K \\ (G_1 + G_2)(1 - \eta_{VZP}) - G_4 = 0 \\ G_4 + G_5 - G_6 = 0 \\ G_3 (1 - \eta_f) - G_5 = 0 \end{array} \right) \quad (2)$$

Where $\overline{G_n} = G_n / G_{com}$

The system (2) of six equations with six unknowns can be written as a product AX = B, where

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$$B=\begin{pmatrix}1\\1\\K\\0\\0\\0\end{pmatrix};\ X=\begin{pmatrix}\overline{G_1}\\\overline{G_2}\\\overline{G_3}\\\overline{G_4}\\\overline{G_5}\\\overline{G_6}\end{pmatrix};$$

$$A=\begin{pmatrix}1 & 1 & 1 & 0 & 0 & 0\\ \eta_{conc} & 0 & 0 & 0 & 0 & 0\\ 0 & 0 & 1 & 0 & 0 & 0\\ 1-\eta_{VZP} & 1-\eta_{VZP} & 0 & -1 & 0 & 0\\ 0 & 0 & 1 & 1 & 1 & -1\\ 0 & 0 & 1-\eta_f & 0 & -1 & 0\end{pmatrix} \quad (3)$$

Solution of the resulting system is $X = A^{-1}B$, where A^{-1} is a matrix inverse to matrix A.

A dimensionless quantity $\overline{G_6}$ characterizing amount of dust contained in the purified air is defined as

$$\overline{G_6} = \frac{\Delta_6}{\Delta} \quad (4)$$

It is obvious that the value $\overline{G_6}$ representing ratio of dust amount transferred for purification and leaving the aspiration system is numerically equal to the value of total purification efficiency η_{com}.

Figure-3 shows a scheme for calculation of the dust emission purification system made according to the scheme with secondary purification of different concentration flow using bag filter (the first layout variant). In view of the simplicity of the scheme, due to the fact that total efficiency of the dust trapping is defined by the efficiency of the swirling flow dust collector defined according to [4, 5] as $\eta_{VZP} = f(L_2/L_{com}, C_2/C_1)$, and efficiency of the bag filter is considered to be a constant (η_f= 0,98according to catalog data for this dust) values of total system efficiency is defined directly from these basic data.

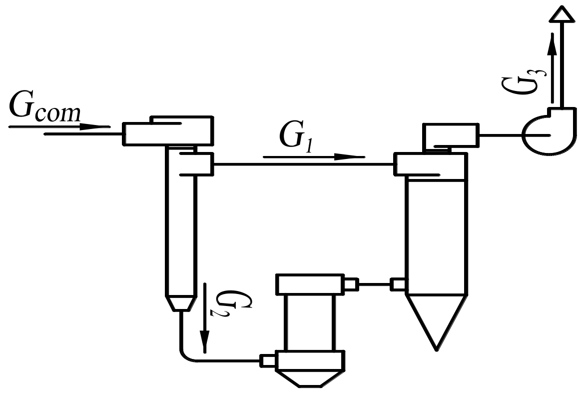

Figure-3. A scheme for calculations of the dust emission purification system made according to the diagram with transfer of flow purified in the bag filter to the secondary input of VZP dust collector.

The goal of the computational experiment was to obtain comparative values of the dust collection efficiency, which, at other equal conditions, characterize the dust emission purification systems made according to the proposed layout schemes.

Results of calculation are shown in Figure-4 in graphical form. As can be seen from the results of the calculation given in the graph, numerical values are approximately the same for both layouts of the dust collection efficiency. At that, both dependences are characterized by maximum values observed in the range of flow division efficiency $\eta_к$= 66…80%. After exceeding the upper limit of the specified range, the value of the total efficiency begins to decrease. This fact is presumably can be a result of increase of number of fine particles which begin to penetrate into the upper input of the VZP dust collector due to increased separation efficiency of the centrifugal dust concentrator.

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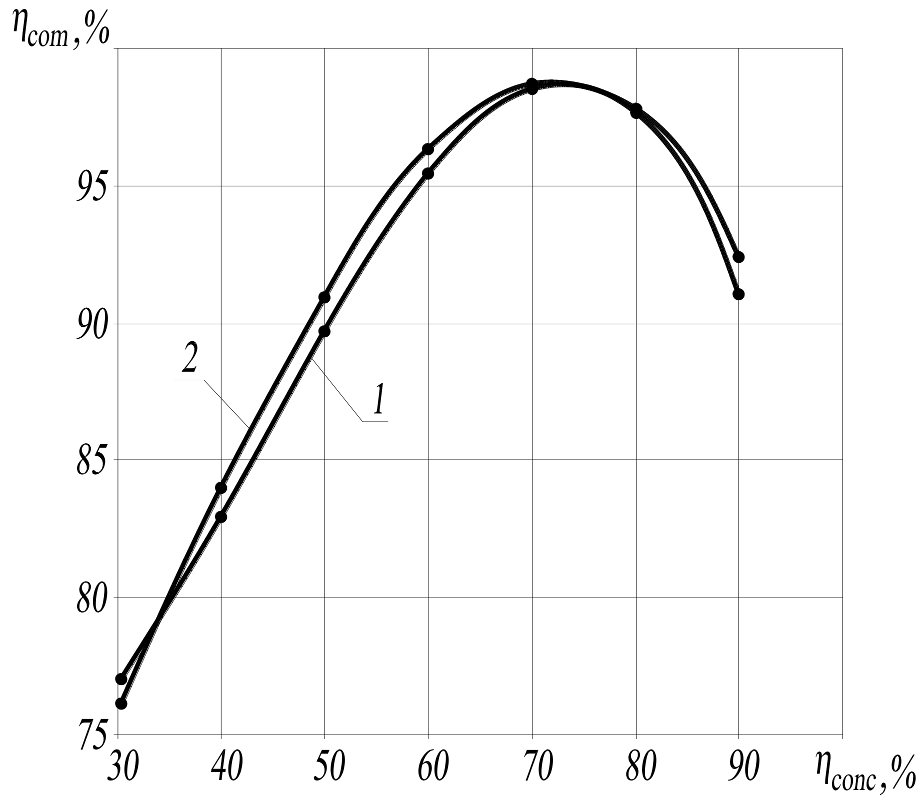

Figure-4. Dependences of total purification efficiency for the first and second variants of the layout schemes versus efficiency of flow separation $\eta_{com}(\eta_{conc})$: 1 - the first layout scheme; 2 - the second layout scheme.

As the efficiency of small fractions trapping by inertial method is lower than in the case of application of the filter, the overall efficiency of the installation decreases.

Due to the complexity of configuration, at similar emission purification efficiency, the second design layout cannot be considered suitable for practical implementation. Thus, the first layout is the most suitable for implementation of the proposed solutions.

CONCLUSIONS

Two variants of layout schemes are developed for dust emissions purification systems of movable and mobile asphalt mixing plants which apply VZP dust collectors, dust concentrators and bag filters;

Analytical study of operation of the equipment based on the proposed layout schemes is carried out;

The data obtained define the effect of flow separation in a centrifugal dust concentrator on total efficiency of both layout schemes;

As a result of the computational experiment, a conclusion is made that application of the first layout variant is preferable as it is the most simple and technological at equal values of total efficiency of dust emissions purification.

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