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INERTIAL DUST CATCHERS EFFECTIVENESS

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Summary. Dry inertial dust catchers (DIDC) application for refinement of transport engines ingoing air is analyzed. The common types of designs and peculiarities of dust catchers are presented. Possibility of further improvement of diesel engine air refinement processes by DIDC using is offered here.

Keywords: dust catcher, air refinement, cyclone separator, effectiveness.

INTRODUCTION

It is well known, that in reliability of transport engines, agricultural and other machines the important role is played by refinement of ingoing air. Therefore, the important problem which arises before scientists and designers of new engineering is the development of effective dust-separating apparatuses [Gackey 1982].

Mechanical dust catchers belong to apparatuses, in which different mechanisms of precipitation are used: gravitational (gravitational dust catchers), inertial (dust precipitation in them occurs as a result of a gas stream direction reversal or a barrier set on its way) and centrifugal (single, group and battery cyclone separators, vortex and dynamic dust catchers). One of the basic varieties of such apparatuses is dry inertial dust catcher (DIDC) [Barth 1964].

Dry inertial dust catchers find broad application in a railway transport (in air systems of internal-combustion engines, cooling systems of traction motors, in ventilation and compressor systems and in other engineering devices) due to their manufacturing and maintenance simplicity. The basic advantages of them comparing to other gases refinement apparatuses are absence of moving parts, reliable activity in broad range of temperatures and pressures, stability of a flow friction, trapping of dust in a dry aspect, simplicity of manufacturing and repair.

The weaknesses of cyclone separators are high flow friction (1200-1500 Pa) and low effectiveness with dust particles size below 5 microns, so they frequently play a role of gases prerefinement apparatuses.

Development of more efficient dust catchers, than used, capable to clear dusty and high-temperature gases in some cases makes the conventional two-stage gas refinement system irrational [Perry 1997].

The research activities connected to development of centrifugal dust catchers which provide sufficient effectiveness at precipitation of superfine dust particles, and also trapping a dust in conditions when other types of dust catchers cannot be applied (for example, in processes with high temperature of gases 1000 - 1200°C). Therefore, despite the narrowing of application sphere marked above, total amount of researches and advanced designs in the field of a centrifugal dust separation remains rather high.

Research of movement of dust particles by mathematical modeling improves and speeds up designing of DIDC, reduces the number of experimental samples and tests at the design stage for achievement of necessary effectiveness of gas refinement.

OBJECTS AND PROBLEMS

Orientation among numerous designs of centrifugal dust catchers is very difficult. There are some publications dedicated to analytical definition of the optimized cyclone separators parameters [Barth 1964, Cooper 1983, Perry 1997]. But not in all cases theoretical modeling of cyclone processes takes into account physical and chemical properties of dust which determine not only effectiveness, but also reliability of the dust-separating equipment. These parameters and their derivatives usually are not included into criteria of optimization, but they justify a variety of cyclone separators designs. Therefore, considering purpose and conditions of application, developers recommend various parities of geometrical sizes of cyclone separators, their forms and co-operating equipment devices.

In the industry reverse-flow and straight-flow cyclone separators, and also their battery composition, apparatuses with counter twisted streams, spiral - whirlwind dust catchers found application.

In [Dmitrienko, 2009] is made an attempt to systematize the information on dry centrifugal dust catchers and to estimate expediency of design modifications on the basis of fractional distribution effectiveness. But not always it can be executed on the basis of experimental methods which require significant resources expenses.

The flow friction of centrifugal dust catchers in most cases is taken into account by experimental coefficients of resistance determined by dust catcher design. Such method is not acceptable for new types of apparatuses.

Method of theoretical calculation of cyclone dust separators resistance for the first time was proposed in 50th years of XX century by German researcher Walter Barth [Barth 1964]. But such method is recommended with reference to cyclone separators, but from the other side, its application interferes with difficulties because of absence of an apparatus velocity field account models in it. Offered in [Cooper 1983, Perry 1997] design techniques of characteristic velocities are of empirical character and deform the essence of the theoretical approach.

For increase of a dust separation effectiveness in centrifugal type apparatuses a lot of modes are used: an intensification of a gas stream twisting at the apparatus input,

decrease of secondary flow of a dust, the organization of efficient unloading of the dust, parallel use of other mechanisms of precipitation of suspended particles, etc.

As a rule, the gained effectiveness is attained by power and capital outlays increase, complication of design, that is increase of manufacturing and operation cost and in some circumstances decrease of reliability. In this connection the importance of technical service, of automatic control equipment of such apparatuses increases.

For increase of operational effectiveness of these devices it is necessary to probe their different schemes. Results of researches can have practical importance not only in transport, but also in those areas of engineering where processes of a dust separation are used, for example, in chemical engineering, etc.

For DIDC different schemes advantages analysis and development of engineering recommendations for selection and calculation of these devices in each case it is necessary to make the theoretical researches of these devices work.

The purpose of the current theoretical researches was research of effectiveness of different schemes of dry centrifugal dust catchers.

In practice cyclone separators NIIOGAZ are widely used (fig. 1a, b): cylindrical (with the elongated cylindrical part) and conical (with the elongated conical section). Cylindrical cyclone separators (fig. 1a) usually belong to high capacity apparatuses and conical (fig. 1b) - to high performance ones. The diameter of cylindrical cyclone separators is not more than 2000 mm, and conical - 3000 mm. In the technical literature there are a lot of publications devoted to dust catchers of "Cardiff" type (fig. 1c), that are characterized by presence of dust-separating pockets VCP. Emersion of these dust catchers connected to the demand of conducting of high performance separation at high pressure and temperature of a gas stream. Also straight-flow apparatus with splitter and vortex separator are presented in this figure (fig1,d).

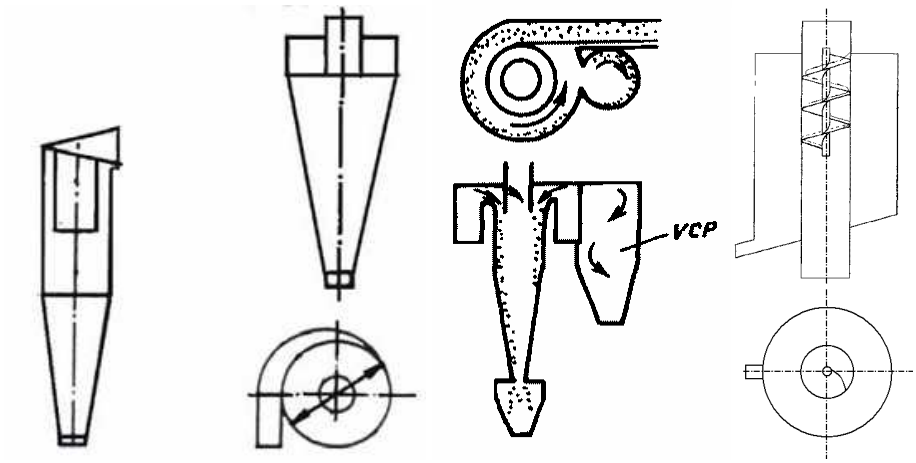

Fig. 1. Different schemes of inertial dust separators: a) cylindrical NIIOGAZ; b) conical NIIOGAZ; c) MK6A "Cardiff"; d) straight-flow dust catcher.

In a basis of the offered method of dust catchers efficiency estimation two main principles laid, they are widely used in practice of centrifugal dust catchers calculation [Barth 1964].

At first, let's review the thesis that fractional effectiveness distribution of the centrifugal dust catcher have logarithmical to the normal law so, can be characterized by two parameters: d_{50} - a diameter of particles which catches with effectiveness of 50 %, and $\lg \sigma_\eta$ - average quadratic deviation of fractional effectiveness distribution function.

And second, conversion of parameter d_{50}, received at conditions ρ_p, W_g, μ_g and D_c to real operating conditions of the cyclone separator ρ^*_p, W^*_g, μ^*_g and D^*_c, distinct from initial, implements on the basis of equality of criteria of Stokes by formula:

$$d_{50}^* = d_{50} \cdot \sqrt{\frac{\rho_p}{\rho_p^*} \cdot \frac{W_g}{W_g^*} \cdot \frac{\mu_g^*}{\mu_g} \cdot \frac{D_c^*}{D_c}} \tag{1}$$

Here: ρ_p is density of a particle of dust, kg / m^3; W_g is gas velocity in cylindrical cross-section of the cyclone separator, m\s; D_c is cylindrical part diameter of the cyclone separator, g; μ_g is dynamic viscosity of gas, Pa*s.

The big quantity of the data available in technical publications on centrifugal dust catchers, has been instanced by formula (1) to equal conditions which more all frequently meet at research of cyclone separators: ρ^*_p = 1930 kg / m^3, D^*_c = 0,6 g, W^*_g = 3,5 m/s, $\mu^*_g = 22{,}210^{-6}$ Pa*s.

By received data analysis conclusion has been made that the coefficient of the cyclone separator ξ flow friction is the unequivocal characteristic d_{50} parameter of the apparatus defined by the formula:

$$d_{50}^* = 64{,}35 \cdot \xi^{-0{,}511}. \tag{2}$$

Here: d^*_{50} is the value of parameter d_{50} under above-stated conditions, in microns;

$$\xi = \frac{2 \cdot \Delta p}{\rho_{\tilde{a}} \cdot W_{\tilde{a}}^2}. \tag{3}$$

Here: ΔP is a flow friction of the cyclone separator, Pa; ρ_g is gas density, kg / m^3.

On the basis of this relation, cyclone separators can be classified as high performance apparatuses and high capacity ones. High performance cyclone separators have, as a rule, high flow friction ξ due to small sizes of input and a solid spiral of a gas stream. So they do not operate at high speeds of gas because of a considerable energy loss. High capacity cyclone separators, on the contrary, have swirling devices with low flow friction, but a sufficient swirling of a stream and a moderate energy loss at high charges.

Sharp decrease of parameter d_{50}, i.e. increase of effectiveness with conservation of ξ constant, is possible to be achieved by some changes of a design (electrocyclone separators or application of the profiled stream-linings). But that can decrease the reliability or increase a cost of operation. We shall analyze one from numerous intensifications of dust separation process, received with the help of "wet" cyclone separators [Perry, 1997; Dmitrienko, 2009]. The considerable increase of dust catch effectiveness is achieved due to elimination of secondary dust flow. These data induce researchers to develop such designs of cyclone separators in which secondary dust flow is minimal.

Application of DIDC in air system of a diesel engine of the main diesel locomotive allows increasing of air refinement level. Cyclone separators are inexpedient to use with a changeable mode of operation as their effectiveness changes at oscillations of gas charge and irregular gas streams. This deficiency is eliminated in battery cyclone separators - multicyclone separators in which the gas stream is distributed between parallel cyclone separators united in one knot. Straight-flow dust catcher with splitter and vortex separator can also be combined with other types of dust catchers or set in battery. For example, effectiveness of 20 battery cyclone separators with diameter of 200 mm can reach refinement level of 0,82, but it is necessary to remember about considerable resistance of cyclone separators. Also it is necessary to use automation devices for the support of operation nominal parameters, taking into account changes of the cyclone separator characteristics at gas unsteady flow parameters.

CONCLUSION

1. Most researchers use the power principles in the standard design techniques of dry inertial dust catchers.
2. Some ways of cyclone separators modernization make design more complex and do not provide considerable increase of effectiveness.
3. Application of dry inertial dust catchers combinations in air system of a diesel engine of the main diesel locomotive allows the increasing of air refinement level.

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ЭФФЕКТИВНОСТЬ СУХИХ ИНЕРЦИОННЫХ ПЫЛЕУЛОВИТЕЛЕЙ

Дмитриенко Д.В.

Аннотация. Проведен анализ сухих инерционных пылеуловителей (СИП), применяемых для очистки поступающего в транспортные двигатели воздуха. Представлены основные типы устройства и особенностей пылеуловителей. Предложена возможность дальнейшего усовершенствования процессов воздухоочистки дизельных двигателей с использованием СИП.

Ключевые слова: пылеуловитель, воздухоочистка, циклонный сепаратор, эффективность.