ADSORPTION METHOD OF PURIFICATION OF EXHAUST GASES OF DIESEL UNITS AT RHEOSTATIC TESTS

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Abstract: There developed device and method designed for mitigation of emissions of diesels, based on application of mixture of sorbents, including bentonite clay, crushed marble and absorbent coal.

Key words: adsorption method, bentonite clays, rheostatic tests, emissions.

Introduction

In recent years has been extensively developing the range of scientific-technological tasks related to use of adsorption processes. As sorbents are mainly applied synthetic materials, while there exists big class of natural silicate sorbents – clay minerals, having high adsorption and catalytic properties.

Bentonite clays have been for a long time drawing attention of researchers, as their composition includes mineral montmorillonite, having interesting structural features and specific properties. They are widely used as sorbents, for which are characteristic selective adsorption, catalytic, filtration and ion-exchange and other properties /1-2/.

Bentonite clays without any extra processing have substantial absorptive capacity in relation to vapors, liquids and substances dissolved in them.

In spite of large number of works dedicated to use of bentonite clays in different sectors of national economy, possibilities of their use for solving many scientific and technical problems of protection of environment are far from being revealed. Especially for Kazakhstan, which has multiple rich and high-quality by content deposits of bentonite clays, the actual task is search of new ways of their use for development of environmental measures.

The purpose of our work is creation of simple by construction and highly effective device and methods of purification of emissions, which form at rheostatic tests of diesel units with application of mixture of Bentonite with other materials having absorptive properties.

Research methodology

Rheostatic tests of diesel units at maintenance factories and repair shops are one of the necessary means of quality control of engine after repair, checking parameters of it's work and regulation of power distribution by different cylinders, adjustment of electric scheme and testing of different elements. They are also necessary before the exploitation of diesel unit in the territory, ни необходимы также перед эксплуатацией тепловоза в местности, environment conditions of which differ vastly from conditions of adjustment of it's parameters.

To our opinion, the most effective way of environmental improvement is creation of stationary purification facilities at stations of rheostatic testing. For this purpose, we suggest stationary two-step combination unit with simple construction, principle of which is based on liquid-sorption purification of emissions of diesels of diesels of locomotives. The first stage of purification is performed with the help of liquid

neutralization. Then, at the second stage, there applied sorbent of mixture of natural materials (Fig. 1).

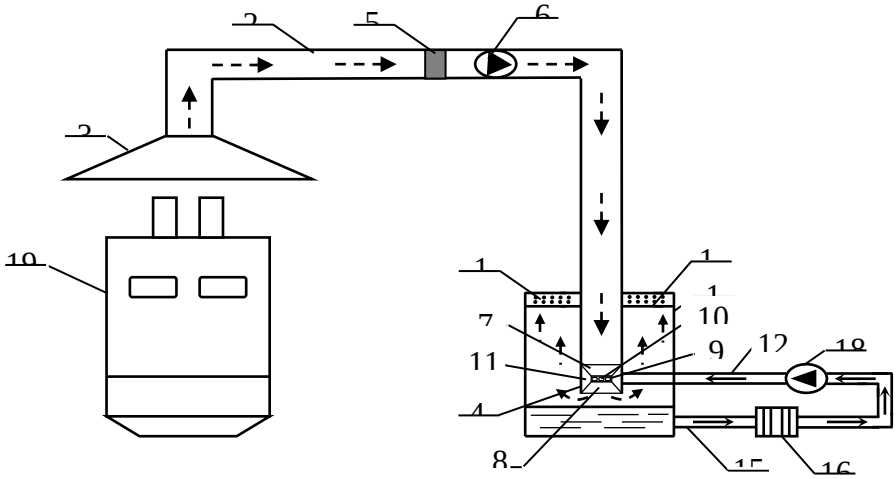

Fig. 38 – Combined stationary system of neutralization of emissions of

The suggested device, provided for purification of emissions of internal combustion engines of diesels, undergoing rheostatic tests, can be also used for purification of emissions from gaseous and solid impurities in different sectors of industry.

The device for purification of emissions comprised of body (1), partially filled with neutralizing liquid, nozzle for input of emission gas (2), device for output of purified gas, made in form of open top of body or separate nozzle for output of purified gases. Nozzle for input of emission of emission (2) is made with hood (3) for collection of emissions at one end and nose-piece (4) at the other end, located in body (1). In nozzle for input of emission (2) there installed catalytic block (5) and pressurizer (6). Catalytic block (5) contains bentonite as catalytic agent. Nose-piece (4) is made of confusor (7) and diffuser (8), connected by throat (9). In walls of throat (9) of nose-piece evenly by it's cut there executed perforated tangential holes (10). Around nose-piece is located camera (11). It is connected to pipeline of supply of neutralizing liquid (12) and housing of nose-piece (4) by perforated tangential holes (10) in walls. In body (1) after nose-piece (4), up to device for output of purified gases there installed filter, made in form of metallic grid strained in top part of body (13), on which located at least one layer of gas-transmitting sorbent (14), for example, bentonite or absorbent carbon.

Results and discussion

Based on experimentally performed laboratory tests we investigated and defined optimum proportions of substances in composition of means, offered for consumption of harmful component of emissions. The most effective as sorbent is mixture composed of crushed bentonite – 60 mass %, absorbent carbon – mass 20%, limestone - mass 20%. Thickness of sorbent layer is 10-15 cm. At thickness of layer less than 10 cm, additional purification of gases in not effective enough, and at thickness of layer more than 15 cm, increases hydraulic friction at slight increase of degree of purification. In bottom part of body (1) located pipeline of output of liquid (15). It is equipped with filter of cassette type (16) with filter elements (17). Pipeline of supply of neutralizing liquid (12) is equipped with pump (18). Filter elements (17) of filter of cassette type can be made of bentonite, absorbent carbon, etc.

The device is working in the following way:

Diesel unit (19) at station of rheostatic testing is located so that it's exhaust pipe were directly under hood for collection of emissions (3).

At working of diesel unit (19) emissions having temperature 400-460^{0}C, are collected under the hood (3), then through nozzle for input of emission (2) through

catalytic block (5) with the help of pressurizer (6) are put through nose-piece (4) to body (1). Stream of emissions is shown on Fig. 1 by dashed arrows.

Stream of emissions is tapered by confusor (7) and increases it's speed. Neutralizing liquid, for example water, by pump (18) under average pressure by pipeline of supply of neutralizing liquid (12) is supplied to camera (11), and then through tangential holes (10) in throat of nose-piece is forwarded to space of nose-piece (4). Stream of neutralizing liquid is shown by continuous arrows.

Neutralizing liquid is ejected by emissions through tangential holes (10) inside, is dispersed and twisted, there happens additional turbulent mixing of fine-divided neutralizing liquid and emissions. Due to high temperature of emissions (600-650 ^{0}C), neutralizing liquid turns into vapor. At that, water-soluble components of emissions – aldehydes, sulfur oxides, higher nitrogen oxides are neutralized, sooty and other mechanical impurities are collected.

Vapor is condensed in diffuser (8) and after that, liquid with soluble substances obtained at neutralization and mechanical impurities, goes to bottom part of body (1) and through pipeline of output of liquid (15) is supplied to filter of cassette type (16), where in filter elements (17) takes place the purification of neutralizing liquid.

The purified liquid by pump (18) through pipeline of input of neutralizing liquid (12) is supplied to camera (11). Then emissions go through stage of sorbent (14) where performed additional neutralization of carbon oxide and nitrogen oxide, and also separation of moisture from emissions. When leaving neutralizing section, temperature of emissions is within 300-370 ^{0}C.

Purified emissions are withdrawn to atmosphere through open top of body (1). Due to dispersing and twisting of neutralizing liquid in tangential holes of throat of nose-piece, there increases the contact of neutralizing liquid and emissions and their additional mixing, which increases the effectiveness of purification of gases.

Located in top part of body layers of sorbent are additional purifiers of emissions and moisture collectors, which also increases the effectiveness of purification of gases. Catalytic block promotes the increase of degree of purification.

Taking into consideration the literary data /3-5/ on presence of catalytic properties at bentonite claysa, and also based on results of our experimental data, obtained at investigation of composition of exhaust gases after transmitting them through bentonite layer, we can describe components of exhaust gases (EG) by the following reactions:ϕ

conversion of CO with water vapor

$$CO + H_2O \rightarrow H_2 + CO_2 \quad (1)$$

recovery of NO by oxides of carbon and hydrogen

$$NO + CO \rightarrow N_2 + CO_2 \quad (2)$$

$$NO + CO \rightarrow N_2\,O + CO_2 \quad (3)$$

$$NO + H \rightarrow N_2 + NH_3 + H_2O \quad (4)$$

$$NO_2 + NH_3 + O_2 \rightarrow N_2 + H_2O \quad (5)$$

decomposition of nitrogen oxide (I)

$$2N_2O \rightarrow 2N_2 + O_2 \quad (6)$$

Catalytic and sorption properties of bentonite clay are activated during use for purification of emissions at the account of high temperature of emissions and presence of carbon dioxide, sulfur oxides and sulfur. At absorption of acid oxides there derives

chemical modification of surface, i.e. improves the physical structure of bentonite as result of increase of content of free silicon acid due to destruction of montmorillonite.

Reduction of concentration of nitrogen oxides (IV) in emissions, undergone system of sorbents, allows us to make conclusion that, besides the abovementioned reactions on surfaces of bentonite clays there proceeds the following reactions, for example recovery of higher nitrogen oxides:

$$NO_2 + CO \rightarrow N_2 + CO_2 \quad (7)$$

$$NO_2 + CO \rightarrow N_2O + CO_2 \quad (8)$$

$$NO_2 + H_2 \rightarrow N_2 + NH_3 + H_2O \quad (9)$$

$$NO_2 + CH_4 \rightarrow N_2 + CO_2 + H_2O \quad (10)$$

At presence in emissions of sulfur or sulphuric anhydrides, the following reactions take place:

$$CaCO_{3\,(sld.)} + SO_3 \rightarrow CaSO_{4\,(sld.)} + CO_2 \quad (11)$$

$$Ca(HCO_3)_2 + SO_2 \rightarrow CaSO_{3\,(sld.)} + CO_2 + H_2O \quad (12)$$

$$Ca(HCO_3)_2 + SO_3 \rightarrow CaSO_{4\,(sld.)} + CO_2 + H_2O \quad (13)$$

The results of experimental trials, obtained at testing of semi-industrial example of the suggested device for purification of EG of diesel units at rheostatic testing, are provided in Table 1. Measurements of concentrations, temperature of components of emissions and pH indexes of neutralizing water, were performed at nominal regime.

Table 1 – Results of experimental tests

Names of indexes	Indicator values		
	Before purification	After purification	Reduction of concentration %
Emissions, t/year	15,622	15,622	
Concentration of harmful components in gases:			
NO_x, t/year	0,05	0,007	86,0
CO, t/year	0,005	0,00095	81,0
C_xH_y, t/year	0,0005	0,000065	87,0
Soot, t/year	0,37	0,0074	98,0

Conclusion

There was defined above-level content of soot, carbon dioxide, hydrocarbons in composition of exhaust gases of diesel unit at rheostatic testing and was revealed the possibility of reducing their concentrations by way of use of stationary liquid-absorption system of neutralization.

As sorbent was suggested the mixture comprised of bentonite, absorbent carbon and crushed marble. The suggested system of neutralization of emissions allows to

reduce content of soot for 98 %, carbon dioxide – 81,0 %, hydrocarbons – 87,0 % and nitrogen oxides – 86,0 %.

There was developed simple by construction device, allowing to perform effective purification of exhaust gases from harmful components.

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