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THE POROUS FOAM DUST COLLECTOR

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Abstract: *Development of the foam capillary porous generators and dust-and-gas collectors of new type was derived from study of pure liquids boiled in the porous structures and managed by different physical fields: mass (gravity and pressure forces), capillary, vibration and wave (ultrasound). The different physical processes such as boiling, injection, suction (condensation), bubbling, foam generation, pseudo fluidization were summarized with a single criterial equation with accuracy ± 20%. The nozzle-free foam generators of air mechanical foam were designed along with its case, inlet and outlet nozzles, a set of grids and sprayer. They help to conduct foam generation processes with high effectiveness under low hydro-and-gas dynamic resistance. For further enhancement of the combined processes of gas mechanical foam and collecting micro-and-ultramicroscopic dust, a dust collector along with its case, inlet and outlet nozzles, a set of grids and sprayer was proposed, which is equipped with defoaming grid porous structure, whereas foam generating and defoaming structures are installed into in case consequently as per the dusty gas movement and sludge collector.*

Keywords: *Efficiency, Effectiveness, GPS, Seismic Protection Methods, Model Porous Foam, Dust Collector, Capillary Porous Structures, Foam Generator.*

INTRODUCTION

Nowadays, a mechanical foam is widely used in dust suppression in mines, and during transportation of dusty materials. Regretfully, the use of mechanical foam for the purpose of dust suppression in the other industries is limited. The application of foam helps quite efficiently influence on possible sources of ignition, which result in fire extinguishing. However, the main foam properties for fire extinguishing are significantly different from the foam used in dust suppression. Therefore, the special trials are required for each individual case, which should determine the optimal relation between performance characteristics and design characteristics of the foam generating devices.

EXPOSITION

Study of dust collector

We [2] have studied a dust collector that contains body, inlet and outlet nozzles, foam generating and foam suppressing structures, sprayer, sludge collector. Wherein, the foam generating porous structure is made of mesh type 0,08x0,14x1, and foam suppressing of type

0,4x0,14x0,08 (AS 1456608, MKI E21F5/04, A 62 C 5/0,4, 1989, No.5). This dust collector has high dust collecting properties, though it is possible to increase specific capacity, as well as improve its operational functions and running time between regenerations whilst retaining the efficiency of collecting micro and ultramicroscopic dust. Limitation in increase of specific capacity is caused by bubbles, which block the mesh cells. The adjustment process in the operational mode is low controlled that is related to low operational stability of gas compressors.

Requirements for increasing running time between regenerations is substantiated because of meshes with small cells that are available in structures ($0,08 * 10^{-3}$). In order to increase specific capacity, improve the operational functions and increase running time of the dust collector between regenerations, the foam generating porous structures are heated by electric current, and have perforated conductive plates. Wherein, the structures are located opposite each other along the movement of dusty gas forming a mixing chamber.

Besides, the foam suppressing porous structure [1,3] is equipped with a perforated conductive plate heated by electric current. The plate is installed at the outlet of mixing chamber (AS 1555517, MKI E 21 F5|04 21, 1990, No.13).

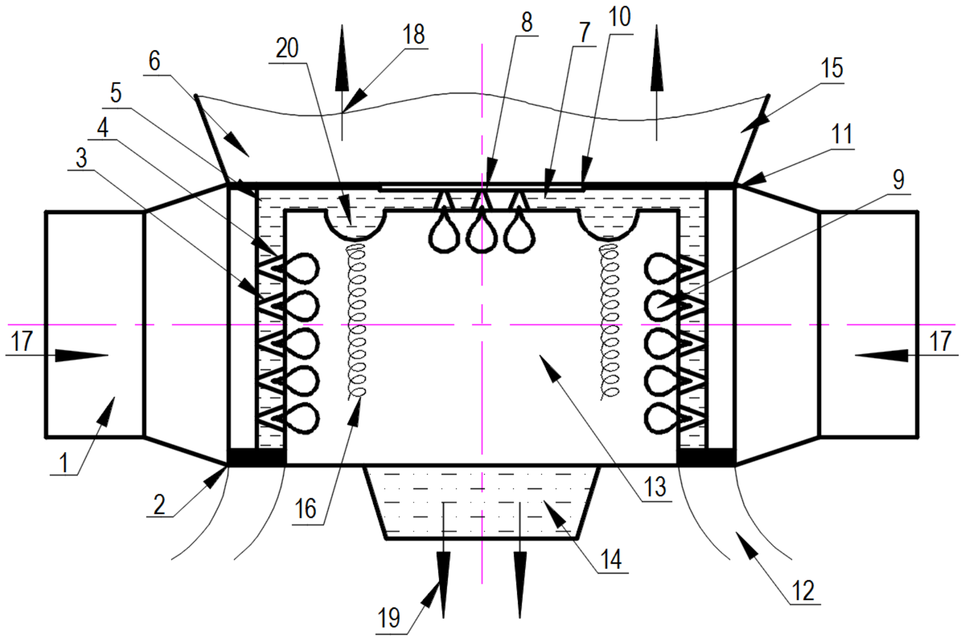

Fig. 1. Dust Collector Design

Dusty gas flow 17 is injected from the opposite side through the dust collector body 1 to body 2 (fig. 1.). Gas flow treatment 17 from microscopic dust is performed in the foam generating porous structures 4, heated by electric current by means of the perforated plates 3, isolated from body 2 by heat-electric isolating gaskets 11. Flow of steam-and-gas mechanical foam 16 is blown by gas flow 17 from cells 9, fed by the foam forming solution 2, supplied from sprayer 5, which is fastened by bolt 6 to body 2. In porous structures 4 the foam forming solution 20 is under a developed bubble boiling process inside and on surface of structure that allows to enhance stability of the multiphase heat-and-hydraulic layer in the sub-critical area and increase capacity of the device.

Having changed the electric current parameters, supplied by electrode 12, the adjustment process in the operational mode of dust collector and under normal mode, consumption of foam forming agent is reduced 1,5 times, and at maximum efficiency the material consumption and dimensions are reduced 1,5 times, weight of device 2,5 times. Gas treated from the microscopic dust is mixed in chamber 13, additionally dust collection processes are enhanced in flow 16 of the mechanical foam, with further dropout of the largest fraction into sludge collector 14. The remained microscopic dust is being collected by the foam suppressing 7 porous structure also fed by the foam forming solution 20 from sprayer 5. The active boiling process in cells 10 is formed by heat flow, which comes from the perforated plate 8 installed at outlet of the mixing chamber 13. This leads to highly effective collection of microscopic particles up to 99,6-99,8%, and destruction of the mechanical foam flow 16 with dropout of particles in a form of sludge 19. The solution boiling process 20 inside and on surface of the porous structures 4, 7 increases stability of the liquid film in heat and hydrodynamic multiphase shear layer.

The diffusive mechanism of dust is when particles are under continuous influence of gas molecules that are in Brownian motion. Wherein, mobility of particles will be increased due to the thermophoresis intensified by the raised difference of temperature between skeleton of the porous structures 4, 7, foam flow 16 of the mechanical foam and dust particles, and because of diffusiophoresis caused by the increased gradient of the foam flow components 16 and the increased enhancement of steam generation process by boiling of the foam forming films 20 in the field of mass and capillary forces, as well as partial condensation of the foam steam 16 at relatively cold dust particles of the dusty gas flow 17.

The developed bubble boiling of liquid on condition of retaining the foam quality and effectiveness of dust collection help increase sizes of cells 9 of the foam generating 4 porous structure and cells 10 of the foam suppressing 7 porous structure that lead to reduction of hydraulic resistance up to 2,5 times, and gas dynamic resistance 1,09 times, as well as extending running time of dust collector between regenerations. The treated gas 18 is removed from body 2 of dust collector through nozzle 15.

Stability of the multiphase shear layer is determined experimentally as per the overheating of metal wall, which was adjacent to the porous structures (table 1) [2].

Stability of the multiphase heat-and-hydrodynamic layer in mesh structures of sub-critical area:

$$\frac{0{,}08x0{,}14x1}{0{,}4x0{,}55}.$$

Table 1

Heat load, x10^4 W/m^2	10	20	40	60	70	80
Wall overburning in relation to steam temperature, K	21	35	46	57	Wall overburning	
	30	42	57	60	63	65

Experimental data for enhancement of the heat and mass transfer processes in the foam generating porous structures of sub-critical area, α, W/(m^2K).

Table 2

Type of Porous Structure	Heat Load, W/m^2,x10^4					
	10	20	40	60	70	80
0,08x 0,14x1	4762	5714	8696	10526	Wall overburning	
0,4x 0,55	3333	4762	7018	10000	11111	12307

As shown in table 2, the porous structure 0,4x0,55 help perform heat and mass transfer processes with maximum boosting (or with maximum capacity of dust collector).

Experimental data for enhancement of the heat and mass transfer processes in the foam suppressing porous structures.

Table 3

Type of Porous Structure	Heat Load, W/m^2,x10^4			
	0,5	1	2	4
0,08x0,14x1	4510	4488	4332	4035
0,4x0,14x0,08	2620	1715	1320	1115
0,55x0,4x0,14	2650	1810	1400	1177
0,14x0,14x0,14	4320	4250	3820	3510

The foam suppressing porous structure (table 3) 0,55x0,4x0,14 also demonstrated low properties for transfer of energy and substance, like structure 0,4x0,14x0,08. Due to the foam forming boiling process inside and on surface, that help actively destroy the foam flow and collect dust of microscopic sizes on account of vapor bubbles growing opposite the foam flow, generated by heat supplied from the heated perforated conductive plate and increase running time between regenerations.

Calculation of hydraulic resistance of the mesh structure for transportation of liquid is determined as per the following formula: $\Delta\rho = \frac{\mu_l m_l h}{p_l F_C K_y}$,

Where: μ_l– liquid dynamic viscosity;

At t=100°C, μ_l= 282x10^{-6}Pa∗s;

m_l- consumption of liquid, $m_l=\beta(\frac{q}{r})|F$,

Where β – liquid excess factor, β=1,1;

q – heat load, q=0,5∗10^4 W/m^2

(minimum value when a boiling starts in porous structures); r=2257 kJ/kg;

F – surface of heat exchange, F=hL=1∗1=1m^2;

F_c – effective cross-section of porous structure;

$F_c=\varepsilon F_c=\varepsilon\delta_\phi L$=0,7∗1,02∗ 10^{-3} ∗1=0,7∗ 10^{-3} m^2;

ε=0,7; δ_ϕ=(0,5+-0,52) ∗ 10^{-3}=1,02∗ 10^{-3}m;

K_r – relative permeability factor:

$K_r=5,5*10^{-7}(\frac{b}{d})^{-1,29}$, $b_r=\frac{0,4+0,55}{2}*10^{-3}$=0,475∗ 10^{-3}m^2;

$d=\frac{0,25+0,2}{2}*10^{-3}$=0,255∗ 10^{-3} m, then $K_r=5,5*10^{-7}(\frac{0,475}{0,255})^{-1,29}$=2,1∗ 10^{-7}m^2.

Hydraulic resistance $\Delta\rho = \frac{282*10^{-6}*2,44*10^{-3}*1}{958*0,7*10^{-3}*2,17*10^{-7}}$=4,8 Pa,

Which is 12/4,8=2,5 times less that in prototype (structure 0,08x0,14x1) despite the proposed structure has lower cross-section values and relative permeability factor.

At the maximum load of dust collector 8∗ 10^5 W/m^2, hydraulic resistance equals: $4,8x\frac{8*10^5}{0,5*10^4}$=768 Pa.

Resistance of the foam dust collectors is 1500-1800 Pa, which is 1,9-2,3 times more. It reduces the power consumption for the pump drive that injects foam forming liquid.

Gas dynamic resistance of the system: perforated plate – porous structure:

$\Delta\rho = \sum_1^2 \xi_{Re}\frac{pW_{in}^2}{2}$, where ρ – gas density, ρ=1,2 kg/m^3;

W_{in}- gas velocity at the plate inlet, W_{in}=3 m/s;

$\sum_1^2 \xi_{Re}$- total rate of gas dynamic resistance for the plate and structure, and is determined as per diagram [2].

For mesh with the cut holes at the edges at relation $\frac{L}{d_2}$=0,16 and f=0,6, rate ξ_{Re}=1; Re=$\frac{w_0 d}{\vartheta}$=$\frac{\frac{3}{0,7}*0,22*10^{-3}}{15*10^{-6}}$=62,2,

Where w_0– gas velocity in cells, w_0=$\frac{W_{вх}}{5}$ m/s; ε = 0,7;

ϑ – kinematic gas viscosity rate; ϑ = $15*10^{-6}$ m^2/s;

d – average diameter of the mesh wire, d=$0,22*10^{-3}$ m. Re>50, where ξ_{Re}=k_{Re*} ξ_{rel}=1,3∗1=1,3. Total rate of gas dynamic resistance: perforated plate – porous structure:

$\sum_1^2 \xi_{Re=}$ ξ_{Re^l}+2∗ ξ_{Re}=1+2∗1,3=3,6.

Finally, the outcome is as follows:

Δρ=3,6∗ $\frac{1,2*3^2}{2}$=9,4 Pa, which 21,1/19,4=1,09 times less than in the known dust collector.

Calculations of the hydraulic and gas dynamic resistance are performed identically for the foam suppressing porous structure and their values also have lower values than in the standard dust collector.

Therefore, gas dynamic resistance of the proposed porous structures is less than for the known mesh dust collector and is considered as minimum resistance for all types of the applicable porous materials (powders, fiber materials, ceramic materials). The main energy losses refer to overcoming hydrodynamic resistance of the multiple layer inside and on surface of the porous structure. However, it has lower value in comparison with the wet foam dust collectors.

CONCLUSION

In conclusion, in comparison with the known dust collectors when the plate is heated by electric current, the foam forming process becomes more controlled other than in the modern air gas compressors that have a low operational stability.

The described advantages of the proposed device with available boiling stable film of the foam forming solution in the heat and hydrodynamic multiphase shear layer were observed with the help of holographic interferometry and speedy filming. High stability of the liquid boiling films in the proposed porous structures was ensured by the equal injection of solution from sprayer by means of combined action of mass (gravity and pressure forces) and capillary forces.

Cost advantage from implementation of the proposed dust collector will be on account of reducing consumption of foam forming solution 1,5 times under alternative modes, increasing specific capacity 1,5 times, reducing hydraulic resistance 2,5 times and gas dynamic resistance 1,09 times, which tend to reduce power consumption for the pump drive and fans, increasing running time between regenerations, simplifying service conditions of the device, enhancing reliability, service life of the device, and capital and operational costs are minimized.

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