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MASS TRANSFER IN CLEANING OF HYDROGEN FLUORIDE GAS IN FILTER APPARATUS

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A B S T R A C T	K E Y W O R D S
In the article, mass transfer process which is occurred as the result of liquid drops motion in the gas flow was studied. Furthermore, absorption of the hydrogen-fluoride component dusty gas in soda ash drops was searched. Consequently, influence of gas velocity and liquid flow to the mass transfer coefficient and purification efficiency of the rotary-filter gas cleaner in its different kind of filters and liquid injection nozzles was studied experimentally. In order to carry out a process effectively optimal quantities of changeable parameters that's liquid flow and gas velocity were recommended.	Rotary-filter, dusty gas, hydrodynamic, mass transfer, mass transfer coefficient, liquid flow, gas velocity, filtration layer.

Introduction

As the world's population grows, so does the demand for more food, especially agricultural products. It is known that mineral fertilizers are widely used in the cultivation of agricultural products. Due to the fact that the processes and equipment for the production of mineral fertilizers are obsolete and need to be modernized, various exhaust gases are released into the atmosphere. This is causing environmental degradation, especially the depletion of the ozone layer, and global warming. Therefore, the current task is to clean the exhaust gases released into the environment through the creation of waste-free technologies and the modernization of existing machinery and equipment. Various dusty gases such as nitrogen, phosphorus and fluorine briquettes are emitted in the production of mineral fertilizers, in particular, hydrogen fluoride gas in the production of dusty superphosphate has a serious negative impact on the environment, so the development of such effective methods and devices for gas purification attracting. Ferganaazot JSC also has a department for the production of superphosphate mineral fertilizers, from which a mixture of hydrogen fluoride gas is released into the atmosphere. The main goal of the study is to capture this emitted gas, return it to the technological process and separate it as a raw material for other related industrial enterprises.

Research Method

The paper examines the process of mass transfer due to the interaction of liquid droplets and gas formed in the device to determine the optimal values of gas velocity and fluid consumption for the purification of secondary hydrogen-fluoride gas formed during the production of superphosphate mineral fertilizers in a wet rotor-filter device. The effect of gas velocity and fluid consumption on the mass transfer coefficient was studied. It was also experimentally determined the effect of different values of the diameter of the nozzle, which drilled holes in the filter material and sprayed the absorption liquid on the working surface.

The process of mass transfer in the gas phase in a rotor-filter apparatus has a complex hydrodynamic and mass transfer character, so it is difficult to describe its passage in the apparatus and develop an equation that fully describes the process. To calculate this process, the mass transfer processes in devices with similar hydrodynamics and phase contact surfaces were studied, and computational equations for the gas phase mass transfer process in the experimental device were proposed. The effect of the consumption of absorption liquid and gas streams on the process of substance transfer in the experimental device is significant. The following equations (1) and (2) are used to calculate these factors influencing the process [1].

Liquid flow through injection nozzles is determined by the next equation, m^3/h;

$$Q_C = \omega_{в} \pi R^2 \cdot 3600 \quad (1)$$

where, R- the diameter of the fluid nozzle hole , mm; ω-liquid velocity, m/s.

The sheber was installed in the gas inlet tube in order to obtain different values of gas velocity. According to the different gas velocities, flow of gas is determined through the formula, m^3/h;

$$Q_Г = \pi \cdot \left(\frac{D}{2000}\right)^2 \nu \cdot 3600 \quad (2)$$

where, *D*–tube diemeter for Pito-Prandtl, m.

As a result of the movement of the droplets formed in the rotor-filter apparatus in the gas phase, a mass transfer is observed, the hydrogen fluoride component in the gas mixture is absorbed into the liquid droplet. To calculate this mass transfer process, it is important to determine the diameter of the drop surface and the volume that varies during the process. When the nozzle diameter varied, the volume of the liquid droplet and the average diameter at which the surface was retained were determined according to the following equation, μm [2,3];

$$d_{32} = \frac{\sum d_X^3}{\sum d_C^2} \quad (3)$$

бунда, dx–the diameter of the droplet forming the main part of the fraction *i*, m;

dc– is the surface diameter of the drop, m; The velocity of the gas passing through the hole in the drum-coated filter material is determined according to the following equation, m / s [4];

$$w_{теш} = \frac{w_{ап}}{\sum F_{теш}} \quad (4)$$

where, $w_{ап}$ – gas velocity in experimental apparatus, m/s; $\Sigma F_{теш}$ – surface of filter's holes, m^2;

The mode of motion of the gas passing through the filter holes is determined by the following equation;

$$\mathrm{Re}_Г = \frac{w_{теш} \cdot d_Г}{\nu_Г} \quad (5)$$

where, $w_{теш}$ – velocity of gas passing through the hole, m/s; ν - kinematic viscosity coefficient of the gas, m^2/s; $d_Г$– drop diameter, μm. The dependence of the rate of component transition in the gas phase on the physicochemical properties of the phases and the process parameters is expressed in the form of criterion equations. The criteria equation proposed by Fresling was chosen to calculate the process of mass transfer in the gas phase in a rotor-filter apparatus. This equation was confirmed on the basis of tests conducted on the mass transfer between a liquid drop and a gas [2-4].

$$Nu_\Gamma = 2 + 0,552 \cdot \mathrm{Re}_\Gamma^{0,5} \cdot \mathrm{Pr}_\Gamma^{0,33} \quad (6)$$

where, Re_Γ – fluid motion regime of passed gas trough the filter;

Pr – quantity of Prandtl for gas phase. Mass transfer coefficient in absorption of hydrogen fluoride component into the liquid drops is calculated by the following equation, m/s [5,7];

$$\beta_\Gamma = \frac{Nu_\Gamma \cdot D_\Gamma}{d_T} \quad (7)$$

where, Nu_Γ – Nusslet's quantity for gas phase; D_Γ – diffusion coefficient in absorption of hydrogen fluoride component into the fluid drops, m^2/s.

In the mass transfer process is occurred between hydrogen fluoride component of gas mixture and fluid drops, the transport number and purification efficiency of apparatus are calculated by the following formula, [8-13];

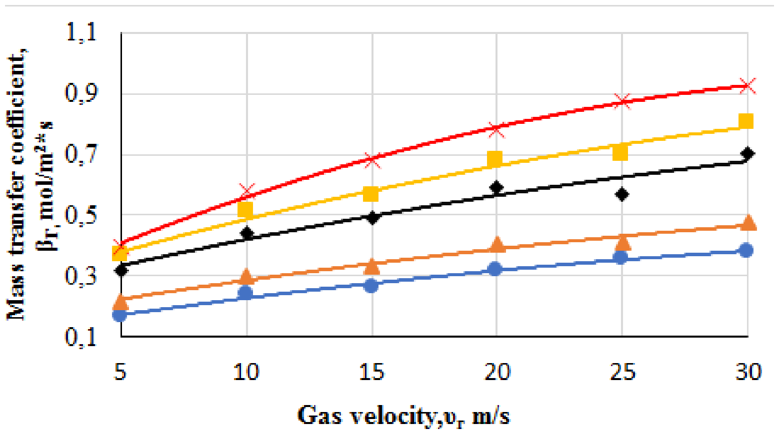
$$n = \frac{\beta_\Gamma \cdot F_K}{G_\Gamma} = \ln\left(\frac{1}{1-\eta}\right) \quad (8)$$

F_K – contacting surface of phases, m^2; G_Γ–gas flow, m^3/h; η– purification efficiency, %.

The Results of Study

The experiment in order to determine the mass transfer coefficient was carried out following two stages, firstly measuring gas and fluid flows, secondly impact of that flows to the mass transfer and cleaning efficiency of apparatus. In the first stage of experiment, in order to measure the gas velocity BA06-TROTEC measurement with the 1,1-30 m/s working range and 0,3% inaccuracy was used. Different gas velocities were obtained having installed the sheber into the gas input tube. Sheber forms the 0^0, 30^0, 45^0, 60^0, 90^0 angels in the input tube after fan [14-21]. The gas flow rate to the apparatus was increased by 5m/s and the speed change interval was set at 5 ÷ 30m/s.

Absorption liquid was selected according to the GOST-3846-10 and supplied through the nozzle with diameters $d_ш$=1mm; $d_ш$=2mm; $d_ш$=3mm; Also, according to GOST-13045-81, the flow rate of the absorption fluid passing through the rotometer RS-5 with a scale of 0-100 was measured for each nozzle in a volumetric manner for the beaker. According to him, when the diameter of the nozzle hole $d_ш$= 1mm, a change in fluid flow according to rotameter readings in the range $Q_{сую}$=0,068÷0,160 m^3/h was observed. According to the rotameter, when the diameter of the nozzle hole $d_ш$ =2mm, the liquid flow rate in the range $Q_{сую}$=0,071÷0,168 m^3/h and when the diameter $d_ш$=3mm, the fluid flow rate $Q_{сую}$=0,072÷0,178 m^3/h [22-29]. In the second stage of the experiment, it was analyzed that the liquid droplets formed as a result of disintegration of the liquid film and secondary decomposition of the liquid falling into the drum through the filter holes of the hydrogen-fluoride component gas move in the gas flow and occur. At this stage of the experiment, the rate of hydrogen-fluoride component gas mixture with the diameter of the hole of the filter material $d_Ф$=2;3;4mm and the consumption of the absorbing liquid Na_2CO_3 sprayed into the apparatus through the nozzle $d_ш$=1;2;3mm were studied. The results obtained are illustrated in the form of diagrams given in Figures 1; 2; 3 below [30-37].



$d_ш$=1 mm and $Q_{сую}$=0,068÷0,160 m^3/h;

Figure 1. Changing of the mass transfer coefficient depends on the gas velocity, $d_ф$=2 mm-const.

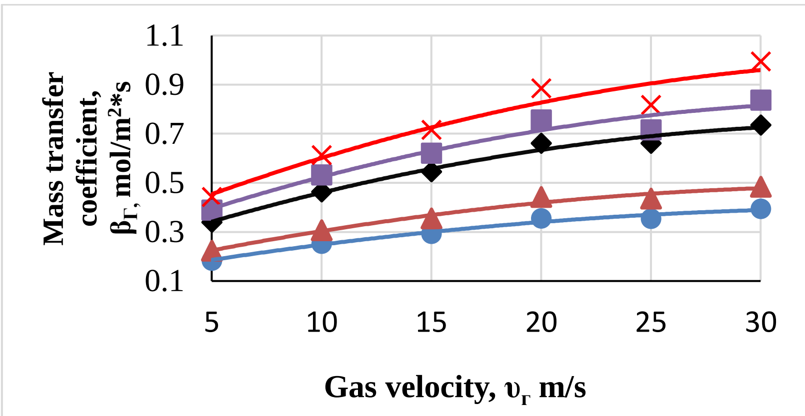
$y = -0{,}0001x^2 + 0{,}013x + 0{,}1116 \quad R^2 = 0{,}9919 \quad (9)$

$y = -0{,}0001x^2 + 0{,}0143x + 0{,}1571 \quad R^2 = 0{,}9757 \quad (10)$

$y = -0{,}0002x^2 + 0{,}0197x + 0{,}2404 \quad R^2 = 0{,}9423 \quad (11)$

$y = -0{,}0002x^2 + 0{,}025x + 0{,}261 \quad R^2 = 0{,}9779 \quad (12)$

$y = -0{,}0005x^2 + 0{,}0373x + 0{,}2339 \quad R^2 = 0{,}9963 \quad (13)$



$d_ш$=2 mm and $Q_{сую}$=0,071÷0,168 m^3/h;

Figure 2. Changing of the mass transfer coefficient depends on the gas velocity, $d_ф$=2 mm-const.

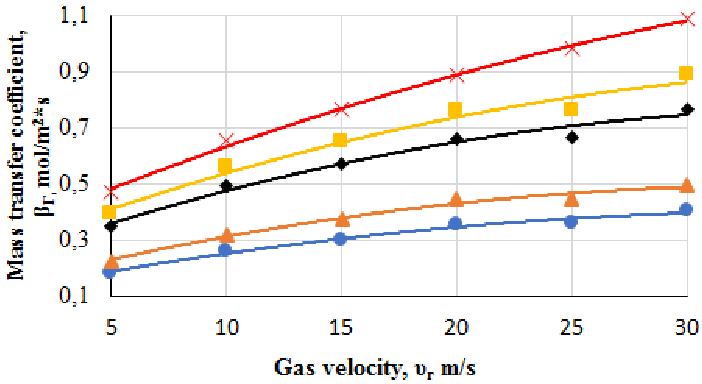
$y = -0{,}0002x^2 + 0{,}0157x + 0{,}1127 \quad R^2 = 0{,}9813 \quad (14)$

$y = -0{,}0003x^2 + 0{,}02x + 0{,}1315 \quad R^2 = 0{,}9753 \quad (15)$

$y = -0{,}0004x^2 + 0{,}0298x + 0{,}2033 \quad R^2 = 0{,}9827 \quad (16)$

$y = -0{,}0004x^2 + 0{,}0324x + 0{,}2447 \quad R^2 = 0{,}9542 \quad (17)$

$y = -0{,}0005x^2 + 0{,}0365x + 0{,}2828 \quad R^2 = 0{,}9357 \quad (18)$



$d_{ш}$=3 mm and $Q_{сую}$=0,072÷0,178 m^3/h;

Figure 3. Changing of the mass transfer coefficient depends on the gas velocity, $d_{ф}$=2 mm-const.

$y = -0{,}0002x^2 + 0{,}016x + 0{,}1134 \; R^2 = 0{,}9859$ (19)

$y = -0{,}0003x^2 + 0{,}0208x + 0{,}1338 \; R^2 = 0{,}9812$ (20)

$y = -0{,}0004x^2 + 0{,}0289x + 0{,}2245 \; R^2 = 0{,}9781$ (21)

$y = -0{,}0004x^2 + 0{,}0313x + 0{,}2627 \; R^2 = 0{,}9711$ (22)

$y = -0{,}0003x^2 + 0{,}0347x + 0{,}3168 \; R^2 = 0{,}9966$ (23)

Figures 1; 2; 3 show that the diameter of the hole of the filter paronite material is $d_{Ф}$ = 2mm, the diameter of the nozzle hole is $d_{ш}$= 1mm and the value of the mass transfer coefficient β_{Γ}= 0.170 ÷ 0.399mol/m^2 ·s change in interval was observed. It was also observed that when the maximum velocity of the purified gas flow is 30 m/s, the value of the mass transfer coefficient is in the range β_{Γ}= 0.382 ÷ 0.927 mol/m^2·s. When the diameter of the nozzle hole is $d_{ш}$=2мм and the minimum velocity of the purified gas flow is 5m/sec, the value of the substance transfer coefficient β_{Γ} = 0.184 ÷ 0.443mol/m^2 ·s is observed to change. It was also observed that when the maximum velocity of the purified gas flow is 30 m/s, the value of the substance transfer coefficient increases to β_{Γ}= 0.395 ÷ 0.995mol/m^2 ·s. When the diameter of the nozzle hole $d_{ш}$ = 3mm and the minimum velocity of the purified gas flow was 5m/s, the value of the substance transfer coefficient β_{Γ} = 0.184 ÷ 0.471mol/m^2·s was observed to change. When the maximum velocity of the purified gas flow was 30 m / s, the value of the substance transfer coefficient increased to
β_{Γ} = 0.402 ÷ 1.09mol/m^2·s [38-58].

Conclusion

As a result of theoretical analysis and values obtained in experiments, the following conclusions were given: -given above 1; 2; and 3 figures show that, in nozzle diameter $d_{ш}$=3 мм and gas velocity $\upsilon_{г}$ =30m/s, also filtering material hole diameter is $d_{Ф}$=2mm the value of mass transfer coefficient is achieved β_{Γ}=1,09mol/m^2·s. It was also found that the minimum value of the mass transfer coefficient is β_{Γ} = 0.143mol/m^2·s when the diameter of the filter material (paronite) hole is $d_{Ф}$ = 4mm and the diameter of the nozzle hole is $d_{ш}$ = 1mm and the velocity of the purified gas flow is $\upsilon_{г}$ = 5m/s. It can be seen that an increase in the velocity of the gas leads to an increase in the mass transfer coefficient;

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