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Research Article

STUDY OF THE MASS TRANSFER PROCESS IN THE WET TREATMENT OF WASTE GASES GENERATED IN THE PRODUCTION OF SUPERPHOSPHATE

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Abstract

In the article, the method of calculation of the process of purification of waste gases generated in the production of superphosphate in a wet method in a rotor-filter experimental apparatus is given. Also, the results of the experiment on the absorption of hydrogen-fluoride gas contained in waste gas into the solution of technical soda in water are given, and the equation for calculating the mass transfer coefficient is recommended. Theoretical and experimental studies mainly selected the optimal values of variable factors.

Keywords

Production of superphosphate, environmental pollution, consumption of absorbent, production of mineral fertilizers.

Introduction

Today, ecology and environmental protection are the most important tasks in every part of the Earth. It is known that the impact of gaseous, liquid and solid waste on ecology and environmental damage is significant. Among these wastes, the impact of toxic waste gases

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generated in the production of mineral fertilizers is enormous [1-4]. This research work is also aimed at cleaning the gases produced and released into the atmosphere in the production of superphosphate and reducing the environmental pollution. An effective method of exhaust gas cleaning was chosen and the optimal construction of the apparatus was developed [5-9]. The developed semi-industrial experimental apparatus with a rotor-filter was used in the treatment of exhaust gases produced in the AS-72M workshop of Ferg'onaazot JSC.

METHODS

Research on the treatment of waste gases generated in the production of superphosphate was carried out in two stages.

In the first stage, the composition and physicochemical properties of the waste gas mixture formed during the production of superphosphate mineral fertilizer were studied. Accordingly, it was determined that 15000÷4500mg of hydrogen fluoride and 1900÷2800mg of dust are formed in 1m3 of gas mixture during superphosphate production. The physical and chemical properties of hydrogen fluoride were studied [10-14].

The study is the second order to determine the optimal value of the device at the first stage, the adsorbent consumption, the gas flow rate to be cleaned and the diameter of the filter hole were selected as variable factors. A 30% solution of soda ash in water was used as an adsorbent [15-21].

The following equations were used to clean the waste gases generated during the production of mineral fertilizers in the rotor-filter experimental apparatus [22-30]. The amount of the hydrogen-fluoride component in the initial gas mixture is determined as follows, m3/h:

$$V_b = V_{b.ar} \cdot x_{bHF} \qquad (1)$$

where Vb.ar is the amount of gas mixture supplied to the device, m^3/h; xbHF- volume fraction of hydrogen-fluoride in the gas mixture, %.

The amount of hydrogen-fluoride in the gas leaving the device, m3/hour:

$$V_{ch} = V_{b.ar} \cdot x_{oxHF} \qquad (2)$$

where oxHF is the volume fraction of hydrogen fluoride in the purified gas flow (outlet), %.

The amount of hydrogen fluoride absorbed into the absorbent, m^3/h:

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$$V_{yut} = V_b - V_{ch} \quad (3)$$

and

$$G_{yut} = \frac{V_{yut} \cdot T_0}{T} \cdot \rho_0 \quad (4)$$

where V_{yut} is the amount of gas absorbed by the absorbent, m^3/h; T_0 - absolute temperature, T is working temperature.

The average driving force of the absorption process in the apparatus is determined as follows.

The partial pressure of the hydrogen-fluoride component at the entrance to the rotor filter is determined from the following equation, kPa:

$$P_{b.HF} = P_{ap.} \cdot x_{b.HF} \quad (5)$$

The molar fraction of hydrogen fluoride in technical soda leaving the apparatus:

$$x_{m.HF} = \frac{\frac{G_{yut}}{M_{FH}}}{\frac{G_{yut}}{M_{FH}} + \frac{Q_{abs.}}{M_{havo}}} \quad (6)$$

The exhaust gases from three-stage stirred reactors have a mixer temperature of 65 °C, and at this temperature, the Henry coefficient for hydrogen fluoride is 1.0 kPa. According to it, the partial pressure of hydrogen fluoride in the equilibrium state with the gas mixture is determined as follows, kPa:

$$P^*_{b.HF} = K \cdot x_{m.HF} \quad (7)$$

The force driving the absorption process in the lower part of the apparatus, kPa:

$$\Delta P = P_{b.HF} - P^*_{b.HF} \quad (8)$$

The partial pressure of the hydrogen-fluoride purified gas stream at the outlet of the mixer is determined, kPa:

$$\Delta P_{chiq} = P_{ap} \cdot x_{ox\,HF} \quad (9)$$

The average driving force of the mass transfer process in the experimental device is determined as follows, kPa:

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$$\Delta P_{o'rt} = \frac{P^*_{b.HF} - \Delta P_{chiq}}{2,3\lg \frac{P^*_{b.HF}}{\Delta P_{chiq}}} \qquad (10)$$

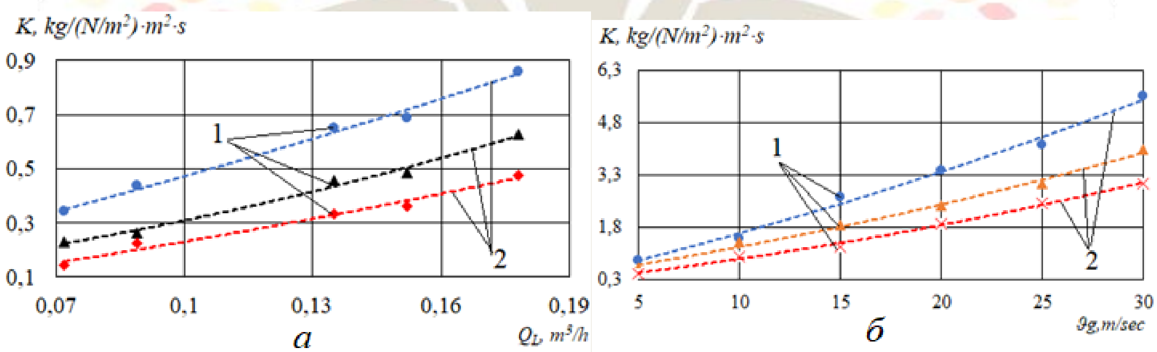
It was recommended to use the following equation to determine the mass transfer coefficient of absorption of hydrogen-fluoride into a solution of technical soda in water in a rotor-filter experimental apparatus, kg/(m²·s·kPa):

$$K = \frac{G_{yut}}{\left(6,28 \cdot R_F \cdot L_B - 0,785 \cdot d_F{}^2 \cdot n_{tesh}\right) \cdot \Delta P_{o'rt}} \qquad (11)$$

where R_F is the radius of the drum, mm; *LB* – drum length, mm; d_F is the diameter of the filter material hole covered with the drum, mm; n_{tesh} – number of holes.

Results

The following results were obtained in the absorption of hydrogen fluoride produced in the production of superphosphate into a solution of technical soda in water [3].



1-experimental values; 2-theoretical values;
Figure 1. a–dependence of fluid consumption on the mass transfer coefficient; b-dependence of the gas flow rate on the mass transfer coefficient.

Figure 1a shows the variation range of the mass transfer coefficient K when the consumption of absorbent liquid is Q_L=0.072÷0.178 m³/h and the speed of the gas flow to be cleaned is 5 m/s. According to it, the small value of liquid consumption Q_L=0.072m³/h and the diameter of filter holes covered on the surface of the d_F=2=2mm; d_F=3mm; When d_F=4mm the value of mass transfer coefficient is K=0.340 kg/(N/m²)·m²·s, the value of mass transfer coefficient is K=0.861kg/(N/m²)·m²·s when the maximum value of absorbent consumption is Q_L=0.178m³/h it became known that it increased to

In Fig. 1b, the range of the gas flow rate to be cleaned is θG=5÷30m/s and the absorbent liquid flow is Q_L=0.178 m³/h, and the diameter of the filter holes covered on the surface of the drumdF=2mm; dF=3mm; When d_F=4mm range of mass transfer coefficient variation is given. According to it, mass transfer coefficient reached the smallest value K=0.475 kg/(N/m²)·m²·s at binary value of gas velocity θG=5m/s. It was also observed that the value of the mass transfer coefficient increased by K=5,550 kg/(N/m²)·m²·s when the gas velocity increased to θG=30m/s.

Also, as a result of processing the data given in Figures 1 a and 1 b, the following empirical functions were obtained and the error between experimental and theoretical values was determined [1-12].

The following empirical functions are available for the speed of the purified gas flow θG=5m/s and the range of absorption fluid consumption Q_L=0.072÷0.178 m³/hour.

$d_Ф = 2мм$ when

$$y = 4,7104x^2 + 3,5504x + 0,0694 \quad R^2 = 0,9923 \qquad (12)$$

When d_F=3mm

$$y = 9,391x^2 + 1,3992x + 0,07450 \quad R^2 = 0,9914 \qquad (13)$$

When d_F=4mm

$$y = 3,8917x^2 + 1,9431x - 0,0035 \quad R^2 = 0,9830 \qquad (14)$$

The range of the rate of change of the flow of purified gas $\vartheta_Г = 5 \div 30 м/c$ and absorption fluid consumption QL=0.178 m³/hour, the following empirical functions are obtained.

When d_F=2mm

$$y = 0,0014x^2 + 0,1344x + 0,125 \quad R^2 = 0,9922 \qquad (15)$$

When d_F=3mm

$$y = 0,0013x^2 + 0,0836x + 0,2605 \quad R^2 = 0,9929 \qquad (16)$$

When d_F=4mm

$$y = 0,0012x^2 + 0,0606x + 0,1525 \quad R^2 = 0,9955 \qquad (17)$$

From these empirical functions, it can be seen that the difference between experimental and theoretical values was 2%. As a result of processing the values obtained on the basis of theory and experiments, the following conclusions were reached [13-29].

CONCLUSION

Purification of fluorine-containing gases produced during the production of superphosphate mineral fertilizers in a rotor-filter experimental apparatus with a 30% solution of technical soda in water resulted in the following results. An equation for calculating the mass transfer coefficient representing the absorption process in the rotor-filter apparatus that cleans gases in a wet method was recommended. The value of the gas flow rate to be cleaned is the largest and the largest value of the mass transfer coefficient was observed at the smallest value of the filter material hole diameter and the highest absorbent consumption, while the decrease of the gas velocity and the largest value of the filter material hole diameter was observed.

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