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THEORETICAL BASED ON THE COEFFICIENT OF SUBSTANCE TRANSFER IN LIQUID AND GAS PHASES IN ROTOR-FILTER DEVICE

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Abstract
Since the calculation of the hydrodynamic regime of the device is complicated and requires various deviations, the calculation of the process of mass exchange is also complicated. Since the device works in a wet method, the process of substance exchange in it is similar to the process of substance exchange in absorbents that work by forming a layer of a film layer.

Keywords: gas-liquid system, gas flow components, hydraulic resistance.

Introduction

In order to calculate the process of mass exchange in the rotor-filter device, it is necessary to determine the areas where phase contact is formed in it. Contacts are formed in the device as follows. Initially, as a result of spraying the working liquid through the nozzle, the liquid falling on the surface of the filter material flows forming a film layer. From there, it flows into the liquid bath, the working liquid collected in the liquid bath also forms a surface of a certain size, and a second mass exchange surface is formed due to the impact of the gas flow on this surface. Then, as a result of the movement of the purified gas stream from inside the rotor to the condenser, the components contained in the purified gas stream are absorbed into the liquid film in the second film layer. Absorption of gas flow components on these contact surfaces characterizes the process of substance exchange in the liquid phase [1].

Research Methodology

The relationship between gas cleaning efficiency and energy consumption is expressed as follows, % [2];

$$\eta_{P\Phi A} = 1 - e^{BK^{X}_{P\Phi A}} \qquad (1)$$

where V and x are constant numbers, which are determined experimentally on the dispersed composition of dust [1-4].

η_{RFA} is expressed by the number of substance transfer to determine the exact value of the cleaning efficiency. The number of substance transfers is determined according to the following equation [5-9]:

$$N_м = \ln(\frac{1}{1-\eta_{РФА}}) \qquad (2)$$

When the numerical value obtained in the equation is in the range of 0.5÷10, the determined value is compared according to Table 1 and the cleaning efficiency of the device is determined.

1 – table. Determining the efficiency of cleaning depending on the number of material transfers

Number of transfers N_m	Cleaning efficiency η_{RFA}	Number of transfers N_m	Cleaning efficiency η_{RFA}
0.5	39.35	4.0	98.17
1.0	63.21	6.0	99,752
2.0	86,47	10.0	99.9953

From the above, it can be seen that the most effective method of accurately calculating the efficiency of dust gas cleaning in wet-processing devices is the research work of K.T.Semrau. In this case, the number of substance transfers is considered to be of great importance [10-17]. Since the device has a gas-liquid system, it is possible to give substance in the gas phase as well. The coefficient of substance delivery in the gas phase depends on the hydrodynamic mode of the device, and the change of the resistance coefficient in the device characterizes the transfer of the amount of substance. In the rotor-filter device, the material supply coefficients are calculated as follows.

First, the mass density of irrigation is calculated according to the consumption of liquid supplied to the device:

$$\Gamma = \rho \frac{3Q}{\Pi \cdot 3600} \qquad (3)$$

in this ρ - working fluid density, kg/m^3*s; Q-the consumption of the working fluid supplied to the device and determined experimentally, m^3/h; P-the perimeter of the contact surface where the film strip is formed.

The film layer formed on the surface of the filter layer as a result of the drop of Q amount of liquid is calculated from the following equation,

$$s_{pl} = \sqrt{\frac{3 \cdot \Gamma \cdot \mu_C}{\rho_s^2 \cdot g}} \qquad (4)$$

in this μ_C - coefficient of dynamic viscosity of liquid, mPa*s.

Through this liquid film thickness, the hydrodynamic regime of the film is found using the following expression,

$$\mathrm{Re}_C = \frac{4\cdot\Gamma}{\mu_S} \qquad (5)$$

The speed of the liquid film is calculated according to the equation proposed by V.G.Levich and T.Khobler from the following expression,

$$w_S = \frac{\Gamma}{\rho_S\cdot s_{pl}} \qquad (6)$$

Using the quantities defined above, the Nusselt number for a liquid film is determined from the following theoretical equation,

$$Nu_S = A\cdot \mathrm{Re}_s^m\cdot\left(\mathrm{Pr}_S^{`}\right)^n\cdot\left(\frac{s_{pl}}{l}\right) \qquad (7)$$

where, A, m, n are coefficients depending on the construction determined by experiment; $\mathrm{Pr}_S^{`}$ - Prandtl number in the liquid phase; *l*-film layer flowing arc length, m [3,6,7,8,9,10]. The process of substance exchange in the liquid and gas phases in the device is inextricably linked, as the coefficient of substance transfer in the gas phase is calculated using the physico-chemical properties and hydrodynamics of the liquid.

In order to calculate the coefficient of material release in the gas phase in the rotor-filter apparatus, it is necessary to calculate the frictional resistance of the liquid and gas phase, and it is calculated from the following theoretical equation [18-24],

$$\lambda = \frac{0{,}11 + 0{,}9\left(\dfrac{w_S\cdot\mu_S}{\sigma_S}\right)}{\mathrm{Re}_G^{0{,}16}} \qquad (8)$$

in this $\mathrm{Re}_G^{0{,}16}$ -Reynolds number, which takes into account the velocities of the gas entering the device and the flow of the liquid film; σ_S - the coefficient of surface tension of the liquid, mN/m^2.

The amount of substance in the gas phase is calculated by the following equation [25-34],

$$Nu_G^{'} = \frac{\lambda}{8}\cdot \mathrm{Re}_G\cdot(\mathrm{Pr}_G)^{1/3} \qquad (9)$$

in this $\mathrm{Re}_G^{0{,}16}$ - Prandtl number for the gas phase.

From the above equations, it can be noted that the mass transfer coefficient in the rotor-filter device increases with the increase in the consumption of the working fluid. As a result of increasing the speed of the gas supplied to the device, the mass transfer coefficient is observed to decrease. In this case, increasing the thickness of the film by increasing the liquid consumption improves the cleaning efficiency. The thickness of the film layer depends on the physico-chemical properties of the working fluid and the size of the holes in the filter layer.

Experiment Results

The diameter of the rotor of the device is supported by a steel mesh and a filter mesh material is covered over it. Paronite material was selected for the filter [35-41]. Paronite material is mainly used in industry to ensure the hermeticity of devices and as a barrier in aggressive and high-temperature processes. Table 2 lists the main technical parameters of the paronite material. The purpose of coating the filter material on the rotor of the device is to study the effect of the hydraulic resistance of the device on the cleaning efficiency. For this, small holes with a diameter of 2, 3, 4 mm were opened in the filtering mesh material. 1The picture shows the appearance of poronite material with holes opened. In the process of cleaning dusty gases, the perforated surface of the filter material is passive, and the non-perforated surface is active.

2 – table. Technical parameters of the paronite material selected for the filter

№	Name of material	Density	Production size	Heat resistance	Absorbency
1.	Poronite	2 g/cm^3	From 1.5×1 m^2 to 1.5×3 m^2	from -50^{0}C up to +45^{0}C	In heated water, the mass increases to 14%

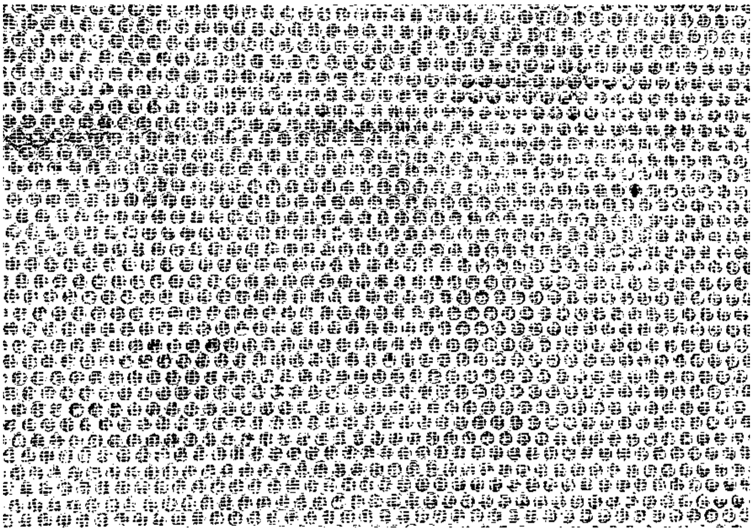

Figure 1. Paronite with small diameter holes.

The working contact surface of the filter material is assumed to be equal to the outlet surface of the diffuser that directs the dust gas to the device. *a*=900 mm; *b*=180 mm. We determine the contact working surface according to the given dimensions by the following equation, m^2;

$$S_{конт} = a \cdot b \qquad (10)$$

In that case, the total contact surface for dimensions *a* and *b* will be equal to 0.325 m^2.
Active and passive surfaces are determined by the following equation, m^2;

$$S_{конт} = S_{акт} + S_{пас} \qquad (11)$$

When determining the active and passive surfaces of the filter material with holes 2 mm in diameter, the number of holes opened by size is 300 pieces; and the number of holes opened by size was 60 pieces. So, the total active surface is 0.268 m^2, and the total passive surface is 0.057 m^2. If we look at the percentage of active and passive surfaces in relation to the total contact surface, the active surface is 82.46% and the total passive surface is 17.53%.
When determining the active and passive surfaces of the filter material, holes with a diameter of 3 mm are opened*a*the number of holes opened by size is 225 pieces; *b* the number of holes

opened by size was 45 pieces. So, the total active surface is 0.229 m^2, and the total passive surface is 0.096 m^2. If we look at the percentage of active and passive surfaces in relation to the total contact surface, the active surface is 70.46% and the total passive surface is 29.54%.
4 mm diameter holes are used to determine the active and passive surfaces of the filter material *a* the number of holes opened by size is 180 pieces; *b* and the number of holes opened by size was 36 pieces. So, the total active surface is 0.202 m^2, and the total passive surface is 0.122 m^2. If we look at the percentage of active and passive surfaces in relation to the total contact surface, the active surface is 62.15% and the total passive surface is 37.84% [19,20].

Summary

1. The hydraulic resistance of the rotor filter device plays an important role in determining the values of the mass transfer coefficient of cleaning efficiency, work efficiency and energy consumption. The hydraulic resistance of the device depends on the local resistances in the diffuser, working surfaces ***A*** and ***B*** and the confusor, and these factors are taken into account when designing the device.
2. According to the conducted theoretical studies, the hydraulic resistance acting on the dusty gas and liquid supplied to the rotor-filter device in the working bodies of the device, the friction force and local resistance coefficients in the working bodies, and the coefficient of mass transfer in the liquid and gas phases are analytical. connections and mathematical models were used.
3. The minimum value of liquid consumption for cleaning 1m3 of dusty gas should not be less than 0.1 liters and the maximum value should not exceed 0.2 liters.
4. In order to catch a drop of liquid leaving the device together with the purified gas, the angle of inclination of the mixer to the xy axis should be higher than 250.

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