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ON THE PURIFICATION OF GASES CONTAINING IMPURITIES OF SMALL CONCENTRATION

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A theoretical analysis was made of the methods used for the purification of gas, containing impurities of small concentrations. A comparison is proposed between absorption and adsorption methods. It is shown that adsorption processes are more advantageous in these cases.

Keywords: gas purification, absorption, adsorption, comparative analysis

Introduction

Numerous ecology problems are related to the purification of air from its impurities. The main problem occurred in the case, when the concentration of the impurity is really small. In these cases absorption in a packed column is frequently used. A high absorption rate should be realized by a suitable chemical reaction between the gas impurity and a liquid absorbent. In reality, the absorption rate is usually very small and as a result, a very high absorption column has to be applied, to reach the expected efficiency.

Absorption

If a gas of $Q\left(m^3/s\right)$ flow rate has to be purified from its impurity with concentration of $C\left(kg/m^3\ gas\right)$ in a packed column (diameter $d\left(m\right)$and a height of the active zone $h\left(m\right)$, height of the packing).

The concentration of the impurity (an active component of the gas) is equal to zero as result of the chemical reaction between this component and the absorbent. In this case the concentration difference in the equation of the mass transfer rate is equal to C. The concentration difference is changing along the active zone height. Thus, it should be used the average value of the concentration difference $\Delta C\left(kg/m^3\ gas\right)$:

$$\Delta C=\frac{C_1+C_2}{2}, \tag{1}$$

where

C_1 and $C_2\left(kg/m^3\ gas\right)$ are the inlet and exit concentrations of the active component in two ends of the active zone.

The chemisorption rate in the column is $J\left(kg/s\right)$ and the volumetric chemisorption rate is $j\left(kg/s.m^3\ active\ zone\right)$.

If $u\left(m/s\right)$, $V\left(m^3\right)$ are the gas velocity and active zone volume, then:

$$V=S.h,\quad Q=S.u,\quad S=\frac{\pi d^2}{4}. \tag{2}$$

If $k\left(m^3\ gas/s.m^3\ actve\ zone\right)$ is the volumetric mass transfer coefficient and $k_s\left(m^3\ gas/s.m^2\ mass\ transfer\ surface\right)$ is the surface mass transfer coefficient, the chemisorption rate equation has the following form:

$$J=k.\Delta CV=k_s.s.\Delta C \tag{3}$$

where

$s\left(m^2\ mass\ transfer\ surface/m^3\ actve\ zone\right)$ is the specific mass transfer surface in the active zone.

Eq.(3) shows that if the volume concentration of the active component is small and the diameter of the

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Table 1 Comparison between the absorption and the adsorption:

$Q=0.4 m^3/sec$, $C=0.01 kg/m^3$, $\eta=99\%$

№	Parameters	Adsorption		Absorption
1	The gas velocity, $u\ (m/s)$	0.7	0.1	1
2	The column section, $S\ (m^2)$	0.57	4	0.4
3	The column diameter, $d\ (m)$	0.85	2.25	0.71
4	The volume mass transfer coefficient, $k\ (s^{-1})$	8.5	1.2	0.5
5	The active zone volume, $V\ (m^3)$	0.046	0.32	0.79
6	The active zone height, $h\ (m)$	0.081	0.081	2
7	The relative decreasing of the volume, $\Delta V\ (m^3)$	1	1	25
8	The relative increasing of the height, $\Delta h\ (m)$	25	25	1
9	The stoichiometric quantity of a liquid phase, $l\ (m^3/s)$	$3.3\ 10^{-5}$	$3.3\ 10^{-5}$	$3.3\ 10^{-5}$
10	The real quantity a liquid phase, $L\ (m^3/s)$	$3.3\ 10^{-5}$	$3.3\ 10^{-5}$	$67\ 10^{-5}$
11	The relative increasing of the liquid phase $\Delta L\ (m^3/s)$	1	1	20
12	The relative increasing of the consummations for the liquid phase, ΔE	1	1	500
13	The pressure drops, $\Delta\varphi\ mm\ H_2O$	80	24	24

column is constant, the increasing rate of chemisorption is a result of the active zone height increase or the increase of the volume mass transfer coefficient:

$$k = k_s . s \qquad (4)$$

Under the chemisorption conditions, when the gas velocity and chemical reaction rate are constant, the mass transfer coefficient does not change significantly. Thus, from Eq.(4) follows that the increase of the input concentration C_1 (respectively ΔC) needs the increase of the specific mass transfer surface, s.

The specific active surface in packed columns is limited by the specific surface of the packing. As a result, it is not possible to increase the volumetric mass transfer coefficient, i.e. for increasing of the column height. This shows that it is better to use adsorption process for gas purification because its specific mass transfer surface is significantly greater compared to packed columns.

The chemisorption in the active zone may be realized by means of absorption in a packed column $(s = 10^2\, m^2/m^3)$ or by the adsorption of a synthetic adsorbent $(s = 10^8\, m^2/m^3)$, because the ratio of the volumetric mass transfer coefficients of the adsorption and absorption is 10^4.

The experimental data for volumetric mass transfer coefficient in the case the SO_2 adsorption by synthetic anionite shows that

$$k = 12.1\, u\ m^3 gas/s.m^3\ active\ zone. \qquad (5)$$

The experimental data for the gas absorption in the packed column [4] show that the volumetric mass transfer coefficient in gas phase for Raschig rings $(50x50x2)mm$ is

$$k = 1.4 kg/m^3 bar.s. \qquad (6)$$

if the gas velocity is $1\, m/s$ and the liquid flow rate is $6\, m^3/m^2 h$.

From (6) it is immediately obtained, that:

$$k = 0.5\ m^3 gas/s.m^3\ active\ zone. \qquad (7)$$

These data allow possibility to make a comparative analysis on the absorption and adsorption, on the basis of the next example (*Table 1.*).

Let to purify airflow of $Q = 0.4 m^3/s$ with concentration of SO_2 $C = 0.01 kg/m^3$ with $\eta = 99\ \%$. Efficiency. The values of the process parameters of chemisorption under the absorption and adsorption conditions are shown in the *Table 1*. The results in the Table show that an increase of the volume ΔV and Δh in the case of absorption, compared to the adsorption.

In the *Table 1* the stoichiometric quantity of the liquid phase $l\ (m^3/s)$ $200\ g/l\ Na_2CO_3$ is obtained immediately. The real quantities of the liquid phase $L(m^3/s)$ are obtained immediately under the adsorption condition $L = l$ from the liquid flow rate under an absorption condition. The relative increase of the liquid flow rate in the case of absorption compared to the absorption condition ΔL can be obtained immediately. The consummations of the liquid phase movement are linear function of the liquid flow rate L and the active zone height, h. As a result, the consummation of the relative increase ΔE is ΔL: $\Delta E = \Delta L . \Delta h$.

Raschig rings $(50x50x5)mm$ are used for the pressure drops comparison. The second adsorption data are valid in the case of lower gas velocity $(u = 0.1 m/s)$.

Conclusions

The obtained results show that the adsorption process is significantly more effective for gas purification compared to the absorption, when the concentration impurities are small.

In these conditions the saturation of the adsorbent is very slow and this is another cause for a real use of adsorption processes for solving ecology problems.

SYMBOLS

C	concentration, $\left(kg/m^3\ gas\right)$
C_1, C_2	input and output concentration of the active component, $\left(kg/m^3\ gas\right)$
ΔC	average value of the concentration difference, $\left(kg/m^3\ gas\right)$
d	column diameter, (m)
ΔE	relative increasing of the consummations for liquid phase,
h	column height, (m)
Δh	increasing of the column height, (m)
J	chemisorption rate, (kg/s)
j	volume chemisorption rate, $\left(kg/s.m^3\ active\ zone\right)$
k	volume mass transfer coefficient, $\left(m^3\ gas/s.m^3\ active\ zone\right)$
k_s	surface mass transfer coefficient, $\left(m^3\ gas/s.m^2\ mass\ transfer\ surface\right)$
l	stoichiometric quantity of the liquid phase, $\left(m^3/s\right)$
L	real quantity of the liquid phase, $\left(m^3/s\right)$
ΔL	relative increasing of the liquid flow rate, $\left(m^3/s\right)$
Q	gas flow rate, $\left(m^3/s\right)$
s	specific mass transfer surface, $\left(m^2\ mass\ transfer\ surface/m^3\ active\ zone\right)$
u	gas velocity, (m/s)
V	active zone volume, $\left(m^3\right)$
ΔV	increasing active zone volume, $\left(m^3\right)$
η	purification degree, $(\%)$
$\Delta\varphi$	pressure drops, $mm\ H_2O$

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