Investigation of oxygen chemisorption during regeneration of a quinhydrone absorbing solution in continuous barbotage layer absorbers

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Abstract - The results of investigations of air oxygen chemisorption during regeneration of a quinhydrone absorbent solution in apparatus with a continuous barbotage layer are given. It is shown that the chemical reaction between chemisorbed O_2 and quinhydrone catalyst reducing form is rapid and occurs in a liquid film. Researching results can be used for the choice of mass-exchange equipment for the process.

Keywords - oxygen sorption; absorbing solution, quinhydrone, barbotage layer; acceleration coefficient.

Introduction

The quinhydrone method of gases purification from hydrogen sulfide is based on the removal of H_2S from gases by an alkaline solution of the quinhydrone catalyst [1]:

$$Na_2CO_3 + H_2S \Leftrightarrow NaHS + NaHCO_3, \quad (1)$$

$$NaHS + \{Q\} + NaHCO_3 = S\downarrow + Na_2CO_3 + \{Q\}H_2, \quad (2)$$

$$\{Q\}H_2 + ½O_2 = \{Q\} + H_2O, \quad (3)$$

where $\{Q\}$ and $\{Q\}H_2$ are oxidizing (quinone) and reducing (hydroquinone) forms of the catalyst.

Equation (3) describes the chemisorption process of the solution regeneration, which consists of two stages - the absorption of air oxygen by the absorbent solution and the interacting of the reducing form of the quinhydrone catalyst with absorbed oxygen. For the regeneration of absorbing solutions with air oxygen in similar industrial processes of gases purification from hydrogen sulfide (Lo-Cat, Stretford, Takahaks, Thylox, Unisulf, etc.), as a rule, use absorbers with a continuous barbotage layer [2]. The effectiveness of the use of this type of apparatus for the quinhydrone method is not established. Therefore, it became necessary to carry out studies on chemisorption of air oxygen by quinhydrone absorbing solution in this type of absorbers.

The aim of the research was to determine the acceleration coefficient of absorption in the process of oxygen chemisorption from the air in apparatus with a continuous barbotage layer.

Experimental part

The research was carried out in a laboratory installation, the main apparatus of which was a glass column (internal diameter of 0.035 and height of 0.5 m) with a built-in bubbler (a porous glass plate with a thickness of ≈5 and a pore size of 0.2 ... 0.6 mm) in the lower parts of the column.

For investigations of the acceleration coefficient of absorption of air oxygen was carried out the two series of experimental studies, which was differed in the type of absorbing solution - soda (10 kg/m^3 Na_2CO_3) or quinhydrone (10 kg/m^3 Na_2CO_3 and 5 kg/m^3 quinhydrone). The other parameters were constant: temperature – 17 ^oC; the height of the solution in the column - 0,25 m. Air flow varied within $(0.78 ... 1.83)\cdot10^{-6}$ m^3/sec. Duration of absorption of oxygen was 480 sec and chemisorption 3600 sec. The dissolved oxygen was stripped from the soda solution by boiling before the investigation. The dissolved oxygen concentration in the solution was determined by Winkler's method. The quinhydrone solution before the studies were saturated with H_2S to reach its concentration of 0.85 kg/m^3. The amount of chemosorbed oxygen was calculated based on analyzes results of the amount of oxidized H_2S in the solution.

To calculate the acceleration coefficient of absorption χ [3], the ratio of the multiplication of the liquid phase mass transfer coefficients in the chemisorption (β_L^{chem}) and absorption (β_L^{abs}) processes on the surface of the contacting phases (F_i) were used

$$\chi = \frac{\beta_L^{chem} \cdot F_i}{\beta_L^{abs} \cdot F_i} = \frac{\beta_L^{chem}}{\beta_L^{abs}} . \quad (4)$$

For calculations of the multiplications in these processes, the basic mass transfer equation [3] was used, in which, in view of the results [4], neglected the diffusion resistance of the gas phase.

Results and discussion

Studies and calculations for the two series showed (Table) that, with increasing air flow, the multiplication of the mass transfer coefficient from the liquid phase on the surface of the contacting phases ($\beta_L \cdot F_i$) increases slightly for both absorption and chemisorption processes. The degree of absorption and chemisorption of the oxygen increases with decreasing of the air flow. However, for the chemisorption process, it is an order of magnitude larger.

Table

Investigation results of the influence of air flow on the processes of the air oxygen sorption

№	Air flow, V_{air}, m^3/sec	Amount of O_2 in the air, N, mole	Degree of sorption, %	Average driving force of sorption, Pa	Rate of sorption, $\Delta N/\tau$·, mole/sec	Multiplication, $\beta_L \cdot F_i$, (m/sec)·m^2
Absorption process						
1	$0.78 \cdot 10^{-6}$	$3.51 \cdot 10^{-3}$	0.79	17224	$5.78 \cdot 10^{-8}$	$22.85 \cdot 10^{-8}$
2	$1.05 \cdot 10^{-6}$	$4.73 \cdot 10^{-3}$	0.63	16920	$6.17 \cdot 10^{-8}$	$24.84 \cdot 10^{-8}$
3	$1.40 \cdot 10^{-6}$	$6.30 \cdot 10^{-3}$	0.48	16830	$6.35 \cdot 10^{-8}$	$25.71 \cdot 10^{-8}$
4	$1.56 \cdot 10^{-6}$	$7.02 \cdot 10^{-3}$	0.47	16668	$6.89 \cdot 10^{-8}$	$28.15 \cdot 10^{-8}$
5	$1.83 \cdot 10^{-6}$	$8.24 \cdot 10^{-3}$	0.40	16775	$6.95 \cdot 10^{-8}$	$28.21 \cdot 10^{-8}$
Chemisorption process						
6	$0.78 \cdot 10^{-6}$	$2.64 \cdot 10^{-2}$	5.11	20042	$3.74 \cdot 10^{-7}$	$116.54 \cdot 10^{-8}$
7	$1.05 \cdot 10^{-6}$	$3.54 \cdot 10^{-2}$	4.29	20209	$4.23 \cdot 10^{-7}$	$129.91 \cdot 10^{-8}$
8	$1.40 \cdot 10^{-6}$	$4.72 \cdot 10^{-2}$	3.54	20332	$4.63 \cdot 10^{-7}$	$142.43 \cdot 10^{-8}$
9	$1.56 \cdot 10^{-6}$	$5.26 \cdot 10^{-2}$	3.53	20365	$5.17 \cdot 10^{-7}$	$158.77 \cdot 10^{-8}$
10	$1.83 \cdot 10^{-6}$	$6.18 \cdot 10^{-2}$	3.17	20441	$5.44 \cdot 10^{-7}$	$166.44 \cdot 10^{-8}$

Calculations have shown that the acceleration coefficient of the absorption $\chi = 5.10 ... 5.90$ ($\chi_{aver} = 5.48$), and the parameters [3] M = 9.95 and R = 7.04. The obtained values of M>R>>1 and $\chi = 5.48$ indicate that the reaction between the dissolved oxygen and the reducing form of the catalyst is rapid and ends in a liquid film, and the partial oxygen pressure over a quinhydrone solution which containing chemosorbed H_2S, is zero [3].

Conclusion

In an apparatus with a continuous barbotage layer, the diffusion resistance of the liquid film during the oxygen chemisorption is large, which prevents the desired rate of the solution regeneration. Therefore, this type of mass-exchange equipment we do not recommend to regenerate the absorbing solution of the quinhydrone method of gases purification from hydrogen sulfide.

References

[1]. V.T. Yavorskiy, A.V. Slyuzar, and Y.A. Kalymon, “Sulfur gas production in Ukraine (review)”, *Chemistry and Chemical Technology,* vol.10, no.4(s), pp.613-619, 2016.

[2]. A.L. Kohl and R.B. Nielsen, *Gas Purification*. Houston: Gulf Publishing Company, 1997.

[3]. V.M. Ramm, *Absorbtsiya gazov* [Absorption of gases]. Moscow: Khimiya, 1976.

[4]. Y.A. Kalymon, Z.O. Znak, A.B. Helesh, and L.V. Savchuk, “Investigation of the absorption process of air oxygen in a device with a continuous bubbling layer”, *Voprosy khimii i khimicheskoi tekhnologii, no.5, pp.102-110, 2018.*