

## THE LIQUID SIDE MASS TRANSFER COEFFICIENT IN A FILM OF LIQUID TRICKLING DOWN AN EXPANDED METAL SHEET PACKING

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The paper presents experimentally obtained values of the liquid side mass transfer coefficient in a liquid film trickling down an expanded metal sheet packing and their analysis based on the model of unsteady absorption.

In the previous paper<sup>1</sup> it has been shown that the mass transfer coefficient on the side of a turbulent gas passing through a bunch of vertical parallel expanded metal sheets can be determined to a high precision with the aid of earlier derived relationships<sup>2</sup>.

In this paper experimentally determined values of the mass transfer coefficient are presented on the side of the liquid film trickling down the same packing and their analysis is based on a model on unsteady absorption.

### EXPERIMENTAL

The apparatus used to carry out the measurements has been described in the previous paper<sup>1</sup>. In order to study the liquid side mass transfer coefficient, absorption of carbon dioxide into water has been selected as a system with negligible gas side resistance. For this reason the experimentally found values of the overall mass transfer coefficient may be thought to represent the liquid side mass transfer coefficient.

The analysis of the air/CO<sub>2</sub> mixture was carried out in an Orsat apparatus with an error of reading  $\pm 0.1$  ml, which represented a relative error of determination equivalent to 1%.

The liquid phase was analyzed by acidimetric titration in a solution containing 70% of pyridine, 20% of methanol and 10% of water. Further the mixture contained barium perchlorate and a small amount of thymol blue as an indicator. The titration agent was sodium methoxide and a potentiometric indication was used to detect maximum change of pH. Tap water used for absorption was titrated in the same way in order to assess the content of free and bound CO<sub>2</sub>.

### RESULTS AND DISCUSSION

After basic processing of primary data and concentrations of absorbed species in the inlet and outlet streams values of the mass volume mass transfer coefficient

related to the specific interfacial surface,  $k_1a$ , were evaluated for the following relation

$$k_1a = \frac{Q(c_k - c_p)}{V \cdot \Delta c_{1g}} \quad (1)$$

The obtained experimental results are summarized in Table I for various densities of irrigation. The mass transfer coefficient in the whole experimentally covered range of gas phase velocities ( $u = 0.56 - 5.79 \text{ m} \cdot \text{s}^{-1}$ ) remains independent of gas velocity. Accordingly, mean values of  $k_1a$  were evaluated for each density of irrigation. The latter dependence can be described with sufficient accuracy by the following analytical expression

$$k_1a = 0.106 \Gamma^{0.969} \quad (2)$$

The mean values of  $k_1a$  served further to calculate  $k_1$  alone using the earlier obtained values of the specific interfacial surface<sup>1</sup>  $a$ . Both  $a$  and  $k_1$  are also shown in Table I.

The expanded metal sheet packing is a ribbed structure with mesh shaped as rhomboids with their longer diagonal being oriented vertically, *i.e.* in the direction of liquid flow. At low densities of irrigation (below about  $0.15 \text{ kg/ms}$ ), the film of liquid forms on the ribbing of the structure; at higher rates of irrigation the whole surface of the sheets of the packing is being gradually covered by the film of liquid blinding the mesh of the sheets as a whole.

Owing to the shape of the mesh the liquid film is being mixed at each point of contact of two ribs of the mesh, which occurs twice along the height of a single mesh. As a first approximation it may thus be assumed that the interfacial mass transfer follows essentially that of an unsteady absorption which may be described by the

TABLE I  
Review of the Results

$\Gamma \cdot 10^2$	2.67	3.75	5.43	8.15	13.75	21.99	34.54
$\bar{k}_1a \cdot 10^3$	3.069	4.508	6.434	9.108	16.050	25.140	36.610
$a$	74.0	80.0	107.0	151.0	182.0	212.0	240.0
$\bar{k}_1 \cdot 10^5$	4.147	5.635	6.013	6.091	8.819	11.859	15.254
$t_e$	1.26	0.69	0.60	0.59	0.28	0.15	0.09
$l \cdot 10^3$	95.07	64.56	72.59	95.16	62.53	47.43	38.69

Highbie model<sup>3</sup>, for which we may write

$$k_1 = \left( \frac{4 D}{\pi t_e} \right)^{1/2} \quad (3)$$

Table I shows also values of  $t_e$  for individual densities of irrigation calculated from Eq. (3). These data suggest that the liquid as it travels down the packing is being intensively mixed every 1.29 to 0.09 seconds.

The last row of the Table I gives the vertical distance,  $l$ , along which the interfacial surface is completely renewed provided that

$$t_e = l/u, \quad (4)$$

where

$$u = \Gamma/Z \quad (5)$$

and for  $Z$  we have<sup>3</sup>

$$Z = 1.19 \Gamma^{0.328} \quad (6)$$

From the values of  $l$  it is apparent that up to the density of irrigation of about 0.15 kg/ms the value of  $l$  spare for the scatter remains constant and from then on systematically decreases, following the changed pattern of the flow over the surface of the packing as depicted above.

#### LIST OF SYMBOLS

$a$	specific interfacial surface (l/m)
$c_p, c_k$	initial and outlet concentration of absorbed species (kmol/m <sup>3</sup> )
$\Delta c_{lg}$	logarithmic driving force (kmol/m <sup>3</sup> )
$D$	diffusivity (m <sup>2</sup> /s)
$k_1$	mass transfer coefficient (m/s)
$l$	mixing length (m)
$Q$	flow rate (m <sup>3</sup> /s)
$t_e$	contact time (s)
$u$	liquid phase velocity (m/s)
$V$	volume of system (m <sup>3</sup> )
$Z$	liquid holdup (kg/m <sup>2</sup> )
$\Gamma$	density of irrigation (kg/m s)

#### REFERENCES

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