GAS-LIQUID MASS TRANSFER COEFFICIENT IN SIEVE TRAY LABORATORY COLUMN

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ABSTRACT

The influence of plate geometry on the characteristics of fluid flow and mass transfer in a laboratory column was experimentally examined using different binary blends. The volumetric gas-liquid mass transfer coefficient depends on the properties of the fluid, the hydrodynamic regime, and the configuration of the gas–liquid contacting device. Prediction of mass transfer coefficient is an important part of gas–liquid contactor design. The individual terms in volumetric mass transfer coefficients are difficult to measure directly.

The aim of this work is experimental study of the kinetic coefficients in distillation of the binary blends in laboratory column at conditions near to model of ideal mixture for liquid phase and ideal displacement for vapour phase.

Key words: *distillation, mass transfer coefficient, tray column*

INTRODUCTION

The influence of plate geometry on the characteristics of fluid flow and mass transfer in a laboratory column was experimentally examined using different binary blends. The volumetric gas-liquid mass transfer coefficient depends on the properties of the fluid, the hydrodynamic regime, and the configuration of the gas–liquid contacting device. The intensity of interfacial mass transfer is characterized by the volumetric mass transfer coefficient ($K_{OG}a$) and determines the amount of gas transferred from bubbles into the liquid phase. Bubble size is an important design parameter which has a strong influence on the hydrodynamic behavior and on the volumetric mass transfer coefficients [1].

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MATERIALS AND METHODS

For direct measurement of overall point efficiency is to make use of the glass lab column is complicated-modification of Oldershaw with take outward overflows [2]. The column has one sieve plate with follow geometric characteristics: diameter 32mm, number of the openings-44, diameters of which is 1.1mm. The height of the overflow is 12mm.

The overall point efficiency, which takes into account effects of mass transfer on tray and in the settling zone, is defined as [3]:

$$E_{OG} = \frac{(y_n - y_{n-1})}{(y^* - y_{n-1})} \tag{1}$$

Once the point efficiency has been deduced from the foregoing relationships it can be re-cast in the form of transfer units:

$$N_{OG} = -\ln(1 - E_{OG}) \tag{2}$$

Mass transfer effectiveness in gas–liquid contactors is most often expressed by means of the volumetric mass transfer coefficient ($K_{OG}a$). This may be correlated, for example, with power input per unit volume and gas superficial velocity, but the resulting correlations do not achieve any degree of generality. Too many phenomena contribute to the values of the film coefficient, k_{OG} and of the specific area a and their combined effect cannot easily be predicted. Separation of k_{OG} and a

in the volumetric mass transfer coefficient is thus a first step for a better understanding of the underlying phenomena [4].

The overall volumetric gas-phase mass transfer coefficient, $K_{OG}a$, is calculated from the following equation,

$$K_G a = \frac{u_G \rho_G N_{OG}}{h_f M} \tag{3}$$

The $K_{OG}a$ value can be predicted if one knows how to estimate the vapour-side mass transfer coefficient K_{OG} and the interfacial area a, individually. Both parameters depends on the bubble diameter [5]:

$$d_S = 3g^{-0.44}.\sigma^{0.34}.\mu_L^{0.22}.\rho_L^{-0.45}.\rho_G^{-0.11}.u_G^{-0.02} \tag{4}$$

Bubble shape, motion and any tendency for the interface to ripple, fluctuate or otherwise deform are all related to the bubble size. In turn, bubble size is determined by the physical characteristics of the system and operating conditions. Equation implies that the bubble size decreases with the increase of both superficial gas velocity and gas density [6].

The bubble diameter is needed also for the calculation of the bubble rise velocity:

$$u_b = \sqrt{\frac{2\sigma}{\rho_L.d_S} + \frac{gd_S}{2}} \tag{5}$$

This equation along with equation (4) was also used to calculate the bubble Reynolds number Re_b needed for estimation of both bubble length l and height h. Terasaka derived the following equations for calculating the ellipsoidal bubble length and height [7]:

$$l = \frac{d_S}{1.14.Ta^{-0.176}} \tag{6}$$

$$h = 1.3.d_S.Ta^{-0.352} \tag{7}$$

The surface area S_b of an ellipsoidal bubble can be calculated as follows [8]:

$$S_b = \pi\frac{l^2}{2}\left[1 + \left(\frac{h}{l}\right)^2 \frac{1}{2e}\ln\frac{(1+e)}{(1-e)}\right] \tag{8}$$

where the eccentricity e is

$$e = \sqrt{1 - \left(\frac{h}{l}\right)^2} \tag{9}$$

In order to calculate the volumetric gas-side mass transfer coefficient $K_{OG}a$, one also needs to know how to calculate the specific interfacial area, a. The formula for its calculation depends on the bubble shape [6]:

$$a = \frac{f_b.S_b}{A.u_b} \tag{10}$$

EXPERIMENTAL RESULTS

Figure 1 shows the profile of the overal mass transfer coefficient $K_{OG}a$ as a function of the superficial gas velocity. The overal mass transfer coefficient $K_{OG}a$ for all mixture increase with an increase in superficial gas velocity.

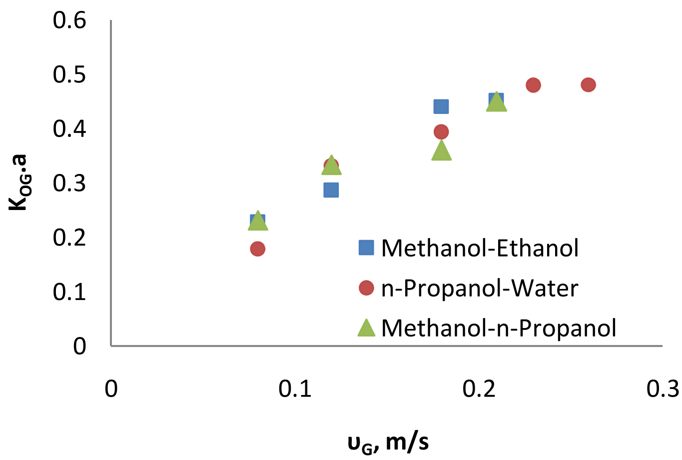

Fig.1. Effect of gas velocity and overall volumetric gas-phase mass transfer coefficient.

Figure 2 shows the effect of pure mass transfer coefficient as a function of the superficial gas velocity. From the figure it is clear that the pure mass transfer coefficient does not depend on the superficial gas velocity, with the exception of the mixture n-Propanol - Water which is slightly increased.

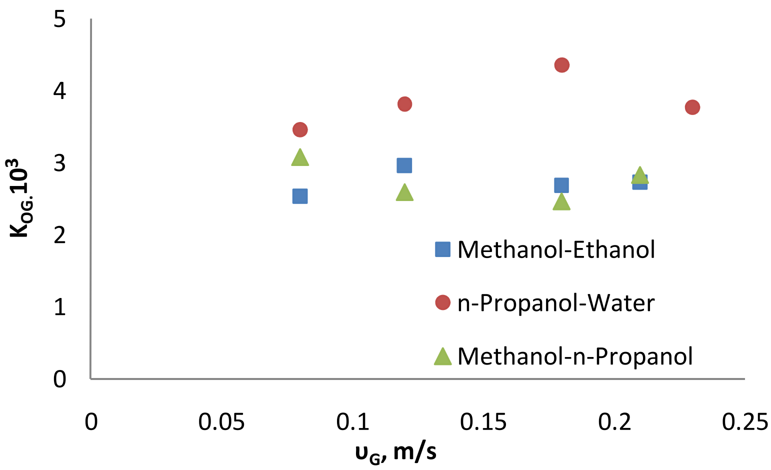

Fig. 2. Relationship between pure mass transfer coefficient and gas velocity

Figure 3 shows the parity plot of experimental She values versus the ones calculated by following equation:

$$Sh = 3.5 \cdot \mathrm{Re}^{0.68} \cdot Sc^{0.47} \qquad (11)$$

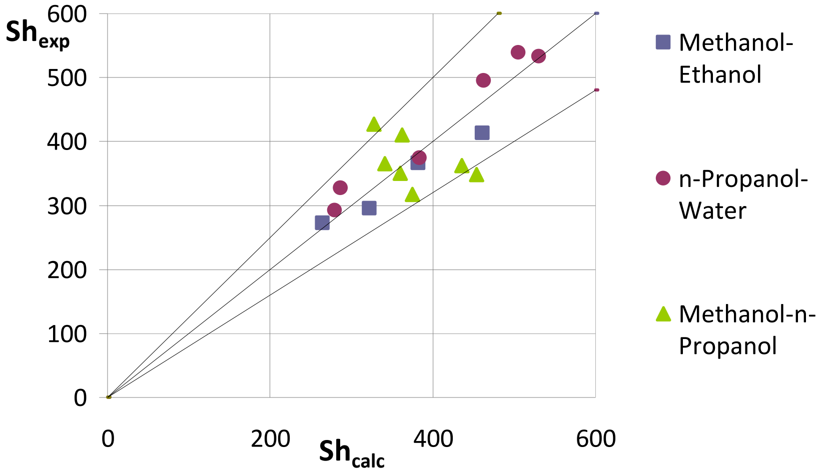

Fig. 3. ***Comparison between experimental Sh values and calculated Sh values***

Predicted values agree well with observed ones. The correlation indicates a good fit of the data (the correlation coefficient was 0.94). The new correlation for the droplet Sherwood number has been presented in the intermediate Reynolds number range.

CONCLUSIONS

Proposed is a model which is applicable for predicting the volumetric gas-side mass transfer coefficient $K_{OG}a$ was measured in binary systems methanol - ethanol, n-propanol - water and methanol - ethanol. Therefore, the model for prediction developed in this work can be applied successfully in glass laboratory column with one sieve tray.

NOMENCLATURE

A	cross-sectional area of the column [m^2]
a	specific interfacial area [m^2/m^3]
d_s	sauter mean bubble diameter [m]
E_{OG}	overall point efficiency [%]
e	bubble eccentricity
f_b	bubble formation frequency [s^{-1}]
g	gravitational acceleration [$m.s^{-1}$]
h_f	aerated liquid height [m]
h	height of an ellipsoidal bubble [m]
K_{OG}	gas-side mass transfer coefficient [$m.s^{-1}$]
$K_{OG}a$	overal mass transfer coefficient [$kmol/m^3.s$]
l	length of an ellipsoidal bubble [m]
M	molecular weight [kg/kmol]
N_{OG}	number of overall vapour phase transfer units
S_b	bubble surface [m^2]
u_G	superficial gas velocity [$m.s^{-1}$]
u_b	bubble rise velocity [$m.s^{-1}$]
μ_G	gas viscosity [Pa.s]
μ_L	liquid viscosity [Pa.s]
ρ_G	gas density [$kg.m^{-3}$]
ρ_L	liquid density [$kg.m^{-3}$]
σ	surface tension [$N.m^{-1}$]

Morton number $Mo = \frac{g.\mu_l^4}{\rho_l.\sigma^3}$

Reynolds number $\mathrm{Re}_G = \frac{d_S.u_G.\rho_L}{\mu_L}$

Bubble Reynolds number $\mathrm{Re}_b = \frac{d_S.u_b.\rho_l}{\mu_l}$

Schmidt number $Sc_G = \frac{\mu_G}{\rho_G.D_G}$

Sherwood number $Sh_G = \frac{K_{OG}.d_S}{D_G}$

Tadaki number $Ta = \mathrm{Re}_b.Mo^{0.23}$

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