Determination of the specific interfacial area in laboratory column equipped with three sieve trays

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Abstract: *The distillation process has been experimentally investigated in a laboratory column equipped with tree sieve trays for to determination of specific interfacial area. The variables studied in the process have been the physical properties of the liquid phase and the physical properties of the gas phase, gas velocity and the hole diameter of the tray. The experiments are carried out in a quartz glass column that can be equipped with tree sieve trays having several fractional perforated areas. The specific interfacial area depends on the properties of the fluid, the hydrodynamic regime, and the configuration of the gas–liquid contacting device.*

The aim of this work is theoretically determination of the specific interfacial area in distillation of the binary blend methanol - water in laboratory column equipped with tree sieve tray.

Key words: *distillation, specific interfacial area, tray column*

INTRODUCTION

The accurate measurement of the gas-liquid interfacial areas is of great importance to estimate reliably the tray efficiencies and optimize the design of distillation columns. The influence of plate geometry on the characteristics of fluid flow and specific interfacial area in a laboratory column was experimentally examined using the binary blend Methanol - Water. The specific interfacial area depends on the properties of the fluid, the hydrodynamic regime, and the configuration of the gas–liquid contacting device. The distillation process has been experimentally investigated in a laboratory column equipped with tree sieve tray for to determination of specific interfacial area.

MATERIALS AND METHODS

The experiments are carried out in a quartz glass column with diameter 0.1 m that can be equipped with tree sieve trays having several fractional perforated areas with a clear section 4.66%. The number of holes in the plate is 52 with a diameter of 3mm, as the overflow limit of each plate is 15mm. The height of the gas-liquid layer on the plate is determined visually, the hydraulic resistance of the plate through the U - tube manometer. [1]. The determination was conducted within the speed range of 0.12 – 0.36 m/s, under atmospheric pressure and full reflux.

The object of this work is theoretically calculated the values of specific interfacial area. The formula for its calculation depends on the bubble shape. The specific interfacial area *a* is a function of the bubble formation frequency f_b, the bubble surface area S_b, cross-section area of the tray *A*, and the bubble rise velocity u_b [2]:

$$a = \frac{f_b . S_b}{A . u_b} \quad (1)$$

The specific interfacial area *a* depend on the bubble diameter [3]:

$$d_S = 3 g^{-0.44} . \sigma^{0.34} . \mu_L^{0.22} . \rho_L^{-0.45} . \rho_G^{-0.11} . u_G^{-0.02} \quad (2)$$

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 [2].

The bubble diameter is needed also for the calculation of the bubble rise velocity [4]:

For the calculation specific interfacial area we need also to calculate the surface area S_b of an ellipsoidal bubble and the bubble formation frequency f_b [5]:

$$S_b = \pi \frac{l^2}{2}\left[1+\left(\frac{h}{l}\right)^2 \frac{1}{2e}\ln\frac{(1+e)}{(1-e)}\right] \tag{4}$$

Where, the eccentricity e is

$$e = \sqrt{1-\left(\frac{h}{l}\right)^2} \tag{5}$$

The bubble formation frequency f_b (number of bubbles formed at the orifice per unit of time) is expressed as:

$$f_b = \frac{Q_G}{V_b} \tag{6}$$

This equation along with equation (2) 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 [6]:

$$l = \frac{d_S}{1.14.Ta^{-0.176}} \tag{7}$$

$$h = 1.3.d_S.Ta^{-0.352} \tag{8}$$

EXPERIMENTAL RESULTS

Figure 1 shows the effect of gas velocity u_G on the specific interfacial area a obtained by theoretical method. As expected, for the binary mixture Methanol – Water the specific interfacial mass transfer area increasing with increment the gas velocity resp. bubble formation frequency.

Figure 2 shows that the specific interfacial mass transfer area obtained by the theoretical method as a function of the aerated liquid height. As it can be seen in Figure 2, the specific interfacial mass transfer area increasing with increment of the aerated liquid height and amended in the range 1846 to 3644 m^2/m^3. For concentration Xw = 5.4 mol% the specific interfacial area has the highest value.

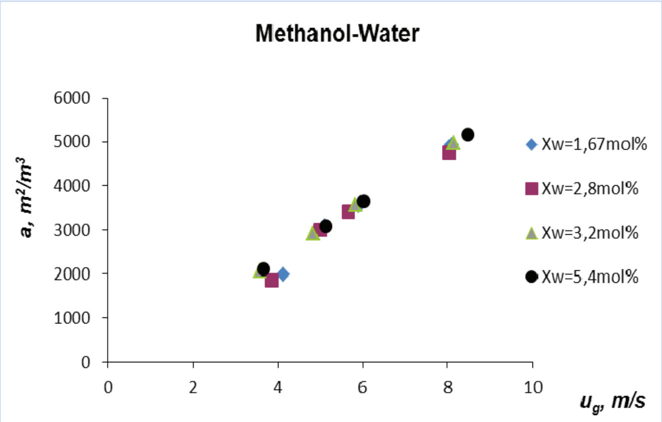

Fig.1. Effect of gas velocity u_G on the specific interfacial area a

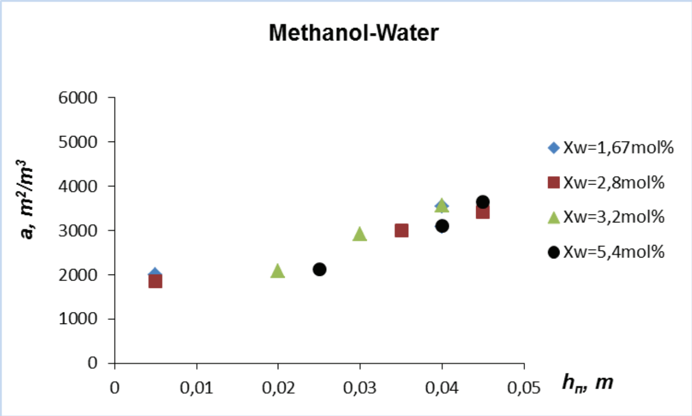

Fig.2. Effect of aerated liquid height h_f on the specific interfacial area a

CONCLUSIONS

The specific interfacial area between gas and liquid phases in a distillation column is a very important feature, which has been researched theoretically in this paper. According to the suggested theoretically method specific interfacial area increased with increment of the gas velocity and aerated liquid height.

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 bubble eccentricity
f_b bubble formation frequency, [s^{-1}]
g gravitational acceleration, [m.s^{-1}]
h height of an ellipsoidal bubble, [m]
l length of an ellipsoidal bubble, [m]
S_b bubble surface, [m^2]
u_G 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 $Mo = \dfrac{g.\mu_l^4}{\rho_l.\sigma^3}$

Bubble Reynolds number

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

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

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This paper has been reviewed