DETERMINATION OF THE LIQUID BACKMIXING COEFFICIENT IN TRAYED COLUMNS

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ABSTRACT

In industry separating mixtures using the process distillation in tray columns, it is of great importance to now hydrodynamic structure of the two-phase flow due to the significant impact on the efficiency of mass transfer process. A tray is defined as a horizontal plate including openings for passing the vapor and liquid phases. Trays are used for intensifying the phase contact and for producing a large surface for good mass transfer for thermal separation processes. In the actual devices the hydrodynamic structure of the two-phase flow is different from the plug flow model for the vapor phase and an ideal mixing in the liquid phase due to uneven velocity profile in the cross section of flow, the gain of the back-mixing in the growth of the transverse non-uniformity of flows, increasing the scale of turbulence entrainment and appearance of stagnation zones.

The aim of this work is experimental determination of the liquid back mixing coefficient by co-current valve tray with flow breaker using "stationary" method and compared with different types of trays. The experiment was carried out in laboratory column which allows the determination of the liquid back mixing coefficient at conditions near to model of ideal mixture for liquid phase and ideal displacement for vapor phase.

Key words: *liquid back mixing, tray column, hydrodynamics*

INTRODUCTION

The design of the trays, the flow phase arrangement, the gas and liquid superficial velocities, and the gas sparger type are among the most important parameters of design and scale-up that affect the extent of liquid back-mixing in tray columns. Published experimental studies on liquid-phase back-mixing in tray columns [1-3] have shown that the axial dispersion coefficient increases, significantly, with increasing column diameter. Although the existence of concentration gradient in the liquid on distillation trays was realized as early as 1936, but recently methods have been evolved for predicting both the nature of the gradient and its effects upon column operation as reflected by tray efficiencies. The concentration gradient is a function of the amount of back-mixing that occurs on a plate. If liquid on a tray is completely mixed, the point or local efficiency is the same as the plate efficiency. In practice, and particularly in commercial-size columns, only partial mixing of the liquid occurs, with plate efficiencies greater than 100 percent being possible. Thus, a proper evaluation of plate efficiencies is directly dependent upon an accurate knowledge of the degree of mixing [4].

MATERIALS AND METHODS

Deckwer divides the liquid mixing into the three categories: ideal mixed, partly mixed and plug flow (PFL). Modelling of liquid mixing is required only for the second case, a partly mixed liquid phase. Mostly, the one-dimensional dispersion model is applied in this case. This model contains only one coefficient, the dispersion coefficient. Akita used the method of measuring the stationary tracer distribution in co-current and countercurrent systems. A concurrent liquid flow is present if the liquid phases flow on each tray in the same direction, whereas in countercurrent liquid flow the direction of the liquid is different from one tray to the next tray. When the distance between the injection point of tracer and the measuring points are sufficiently long, it my be

reasonable the one dimensional diffusion model is applied and the liquid back-mixing coefficient is used to express the characteristics of the liquid mixing [5].

To conduct the necessary experiments was used a pilot plant. A single tray of rectangular column section was used in this study. The column was constructed from Porspex. It was made in two sections with the test plate flange between them.

The concurrent valve tray with flow breaker (CVTFB) contained 32 standard co-current valves which have an overall diameter of 0.048 m. Six flow breakers are placed at 0.14 m each along the plate. Each separator has a slope of 60^0 with respect to the plate base. The tray, valves and the flow breaker are made of stainless steel [6]. Other types of trays which in use in this research are co-current valve tray (CVT), "Glitsch" valve tray and sieve tray.

Based on material balance for two sections of the column is obtained equation describing the transfer of the tracer:

$$\frac{d^2c}{dz^2} - \frac{wl_0}{D_L} \cdot \frac{dc}{dz} = 0 \tag{1}$$

To solve equation (1) we must accept the following assumptions:

- The flow of gas and liquid along the entire section of the tray are constant;
- The liquid entering the tray is assumed to be perfectly mixed;
- The diffusion coefficient a long of the tray is constant.

After assumptions and logarithm of equation (1) is obtained:

$$\ln \frac{c}{c_0} = \frac{wl_0}{D_L} \cdot (z-1) \tag{2}$$

For determination of diffusion coefficient by equation (2) it is sufficient to know the concentration in the two sections of the column. For a better accuracy, the concentration of the tracer is determined in several sections of the apparatus and a graphic builds up to determine the tangent of an angle, which helps calculating the liquid back-mixing coefficent [7]:

$$D_L = \frac{wl_0}{2,303 tg\alpha} \tag{3}$$

The liquid velocity is defined the following equation:

$$w = \frac{V}{bh_0} \tag{4}$$

The tangent of an angle of the resulting rights was defined from method of least squares:

$$tg\alpha = \frac{\sum y_i x_i}{\sum x_{2i}^2} \tag{5}$$

where: $$y_i = \lg \frac{c_0 - c}{c_i - c} \quad (6)$$

$$x_i = (1 - z_i) \quad (7)$$

For determining the concentration of tracer of each tray is provided with a 9 sampling orifice at a distance of 0,1 m from one another a long of the tray. The concentration of tracer in the bubbler layer is maintained under 2 kg/m^3, to employing the linear dependence between the conductivity and the concentration of NaCl in solution. The conductivity cell was connected with the conductivity monitor of the type OK/102 “Radelkis”.

EXPERIMENTAL RESULTS

Experimental results on the liquid phase mixing are present in Figue 1 where the values of the liquid back-mixing coefficient D_L are plotted against the gas velocity w. As can be seen the liquid back-mixing coefficient increasing with the increase in the gas velocity for all four different types of trays. This increase of the liquid back-mixing coefficient was most pronounced in co-current valve tray (CVT) and amended their values from 1,48 to 5,5 m^2/s. For sieve tray and “Glitsch” valve tray the values of the liquid back-mixing coefficient has similar values. The presence of flow breakers mounted significantly lower the liquid back-mixing coefficient, which is a prerequisite for better mass transfer.

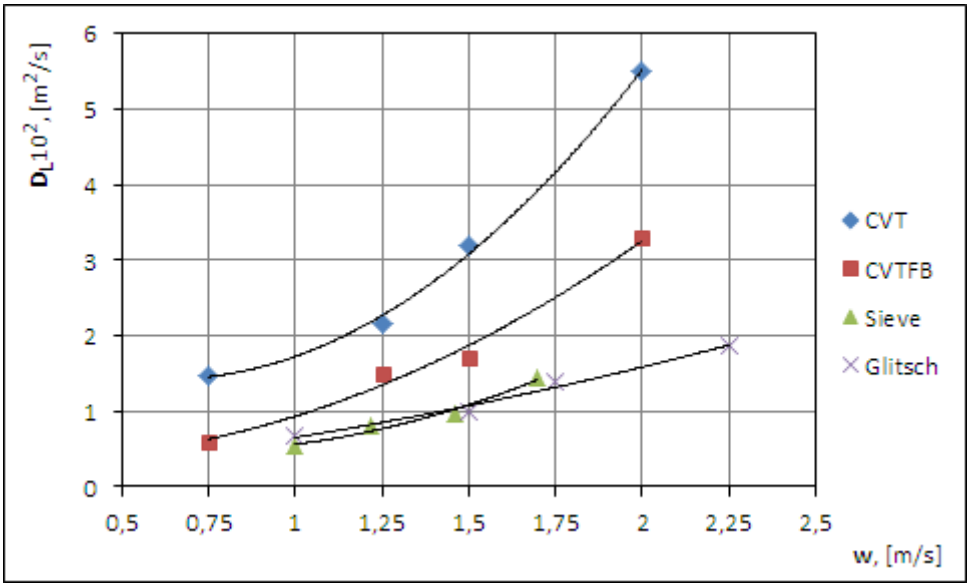

Fig.1. Back-mixing coefficient in the liquid phase as a function of the gas velocity for the four different types of trays at liquid flow rate per unit of bubbling area 2.08 m^3/m.s

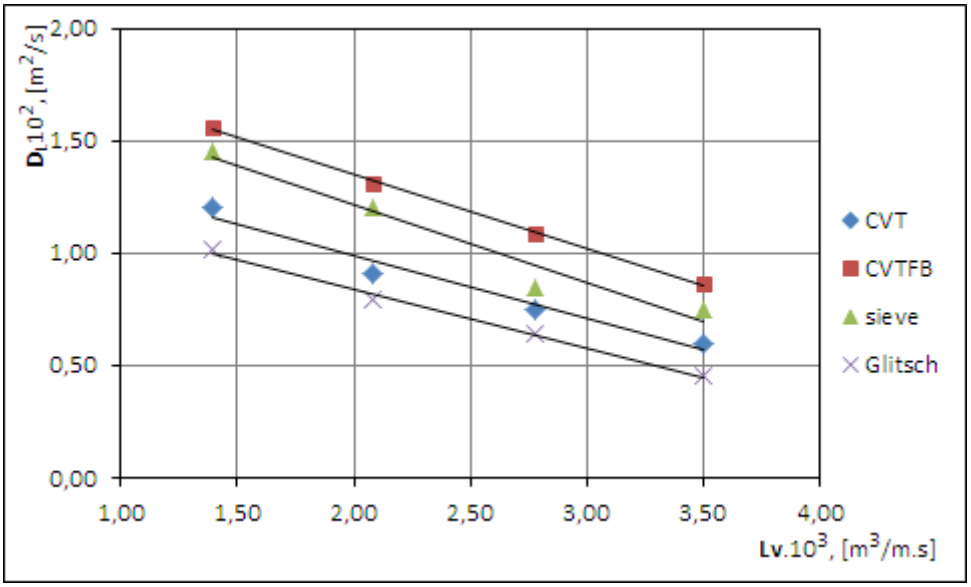

Fig.2. Back-mixing coefficient in the liquid phase as a function of liquid flow rate per unit of bubbling area for the four different types of trays at vapour phase velocity 1.5 m/s

The liquid flow rate per unit of bubbling area *Lv* obtained in the present study for all different types of trays Figure 2 indicated that when liquid flow rate per unit of bubbling area increases, the liquid back-mixing coefficient monotonous decrease.

After the processing of the test results by the method of least squares is obtained the following relationship for calculating the liquid back-mixing coefficient for co-current valve tray with flow breaker:

$$D_L = c.w^n.Lv^m \quad (8)$$

where c=2,04.10^{-2}; n=0,96; m=0,10
c=2,75.10^{-5}; n=1,76; m=-0,90 – sieve tray
c=9,33.10^{-5}; n=1,61; m=-0,69 – co-current valve tray
c=3,28.10^{-5}; n=1,05; m=-1,07 - “Glitsch” valve tray

The calculated values from equation (8) for liquid back-mixing coefficient D_L are differ no more than 8,2 %.

NOMENCLATURE

b	length of the overflow threshold [m]
c_i	concentration of tracer in a place of measured [kg/m^3]
c	concentration of tracer in a place of feeding with tap water [kg/m^3]
c_0	concentration of tracer in a place of introducing [kg/m^3]
D_L	liquid back-mixing coefficient [m^2/s]
h_0	weir height [m]
l_0	distance passed by the liquid [m]
L_V	liquid flow rate per unit bubbling area [m^3/m.s]
w	gas velocity [m/s]
V	liquid flow in the column [m3/s]
CVT	co-current valve tray
CVTFB	co-current valve tray with flow breaker

CONCLUSIONS

An important influence of the gas velocity and liquid flow rate per unit of bubbling area was found on the liquid back-mixing coefficient determination for a co-current valve tray with flow breaker and compare with other types of trays. For all different types of trays the liquid back-mixing coefficient increases its values with increasing the gas velocity and decreases its values with increasing the liquid flow rate per unit of bubbling area. Derived is an equation relating the experimental data for co-current valve tray with flow breaker was obtained from the results describe above. The presence of flow breakers mounted significantly lower the liquid back-mixing coefficient, which is a prerequisite for better mass transfer.

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