COMPARING THE EFFECTIVENESS OF THE PROCESS DISTILLATION BETWEEN COLUMNS WITH ONE AND THREE TRAYS

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ABSTRACT

Increasing the size of the apparatus, particularly the large-scale transition from laboratory to industrial devices leads to lower efficiency. This lowering of the efficiency of the apparatus represents the scale effect which is a result of uneven distribution of flow and proportion of the phases in the cross section of the large apparatus, increasing the scale of the turbulence.

The present work is a contribution in this field, which is quite actual in the last years. A comparison is made between two columns with sieve trays of different sizes in order to establish the influence of the scale effect on the process efficiency by distillation.

Key words: *point efficiency, sieve tray, distillation*

INTRODUCTION

Mass transfer efficiency in distillation is associated with the fluid dynamics on a sieve tray that determines the dispersion structure or the contact area between the gas and liquid phases. The traditionally perceived picture of the froth regime consists of bubbles in a liquid continuous phase and that of the spray regime consist of droplets in a gas continuous phase. These definition of froth and spray regime suggest a sudden change in the nature of two-phase mixture in the transition zone and ask for two separate expressions of interfacial area to predict the tray efficiency in these two regimes [1]. Liquid entrainment is certainly one of the effects with the significant influence on tray efficiency. Colburn introduced the apparent tray efficiency as a possible way for the tray number estimation. Discussing the effect of entrainment on the tray efficiency, by following Colburns assumptions [2]:

- Liquid is completely mixed on tray;
- Liquid entrained from the top tray is thrown backward on the tray and the entrained liquid causes internal liquid circulation within the column;
- Change in concentration of the transferring component in the liquid phase remains the same on two successive trays;
- Mass transfer in the settling zone is neglected.

It has been studied the local efficiency in distillation of binary mixture Methanol-Water under the conditions of completely mixed liquid phase and the alternate plug flow model for the vapor phase. To approach these ideal models of motion of the two phases the experiments were conducted in small scale laboratory glass column with one and three sieve tray. Liquid flow on circular trays is non-uniform having large values from the inlet weir to the outlet weir in the center of the tray and low values near the edges of the tray. This problem has been investigated and it has been shown that flow non-uniformity has a hindering effect on tray efficiency only in columns with diameters larger than two meters [9].

MATERIALS AND METHODS

The first stage of this research is to determinate the overall point efficiency. In the literature exist many authors which are providing different models for determining the local point efficiency. Both the number of theoretical plates and the column efficiency are necessary for the design of a sieve tray column. The prediction of theoretical plates is highly developed and based on rigorous computer models. However, relatively little attention has been given to the prediction of the tray efficiency. The column efficiency is deduced from the point efficiency. The determination of the point efficiency requires the knowledge of the interfacial surface area, liquid and vapor residence times, and liquid- and gas-phase mass transfer coefficients.

Several models have been proposed to describe the sieve-tray efficiency. All of these models are semi-empirical and do not take into account the two regimes that prevail on a crossflow tray ("spray" and "bubbling" regimes). Prado and Fair develop a purely theoretical model for the prediction of the point efficiency for a water-air system [3-5].

The conventional method for the design of tray towers is based on calculation of the number of equilibrium stages necessary for the specified separation criteria, with a correction for the tray efficiencies [6]. According to the written above the point efficiency of sieve tray is expressed by concentrations y_n with the equilibrium value of y*:

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

From the measured experimental data are calculated vapor phase velocities and vapor flow rate. The vapor phase velocity based on total column cross sectional area is calculated from this equation:

$$w_G = \frac{V_G}{F} \tag{2}$$

Where V_G is the vapor flow rate and could be estimated as follows:

$$V_G = \frac{L_F . \rho_F}{\rho_V} \tag{3}$$

For direct measurement of overall point efficiency were used two different glass laboratory column. The first one is a glass laboratory column with complicated modification of Oldershaw with take outward overflows was used. The column has one sieve plate with following geometric characteristic: diameter 32 mm, number of the holes 44 with diameter 1.1 mm. The height of the overflow is 12mm. The column was equipped with glass flask with liquid volume about 1l and electric heater. On the top of the column a glass condenser was equipped [7].

The second column is made entirely from quartz glass. The column has a diameter of 0,1 m and is equipped with three overflow trays. The diameter of trays is 100 mm. The number of holes in the tray is 52 with a diameter of 3 mm, as the overflow limit of each tray is 15 mm. The column was equipped with metal flask with a volume about 20l and electric heater with total power 11 kW. The installed column is described in details in the work of Radev et.al [8].

All the experiments for both installation columns are carried out under atmospheric pressure and in full reflux. The vapor-liquid equilibrium of the system was estimated from the vapor pressure of pure component and from the liquid phase activity coefficients, where physical-chemical properties were taken from literature [9]. Analyses of samples of binary mixture Methanol-Water were accomplished with Abbe refractometer. The temperatures were measured with local thermometers in bottom and top of the column. It was observed that two phase layer produces stable layer without break-down of liquid and an insignificant quantity drops. The composition of the inlet and outlet vapor and liquid concentrations, entering and leaving a certain sieve tray, as well as the vapor-liquid height and the volumetric flow of reflux were determined.

EXPERIMENTAL RESULTS

Figure 1 show that the calculated value of the point efficiency varies as a function of vapor phase velocity in the column equipped with one sieve tray and the column equipped with three sieve trays for binary mixture system of Methanol-Water at atmospheric pressure.

From the figure we can conclude that the point efficiency which is calculated from experimental data decrease with increasing the vapor phase velocity independently the different size of the columns. As we are expecting the small difference of the column size did not affect substantially over the local efficiency.

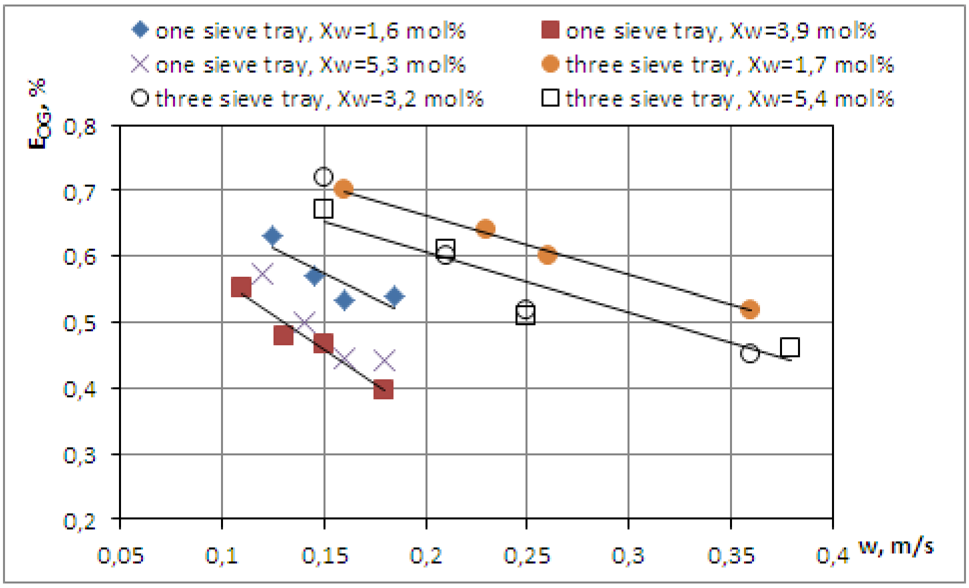

Fig. 1. Comparison the point efficiency as a function of vapor phase velocity

CONCLUSIONS

The comparison of the experimental results taken from two different size tray columns is showing that there is negligible effect over the point efficiency.

NOMENCLATURE

E_{OG}	Point efficiency [%]
F	Cross area of the column [m^2]
V_G	Vapor flow rate [m^3/s]
L_F	Reflux flow rate [m^3/s]
w	Vapour phase velocity [m/s]
y*	vapor mole fraction in equilibrium with the liquid exiting the tray [mol%]
y	vapor mole fraction [mol%]
ρ_L	liquid density [kg.m^{-3}]
ρ_G	vapor density [kg.m^{-3}]

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