EFFECT OF MARANGONI BY RECTIFICATION OF MIXTURES OF ALCOHOLS

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ABSTRACT

The effect of Marangoni occurs when, due to changes in temperature and concentration, gradient of the surface tension is formed at the interphase boundary which has certain influence on the dynamics of wetting of the trays in a rectification columns. The influence of the surface tension on the efficiency (effect of Marangoni) was determined using experimental data obtained with model mixtures methanol-ethanol and isopropyl alcohol-water. The changes of the stabilization M-index with the change of mixture compositions was analyzed to find the effect of surface tension on the experimental data obtained for the local efficiency (E_{OG}) of the model mixtures. The local efficiency was found to increase from 82 to 98% (about 20%) for the positive mixture isopropyl alcohol-water while for the neutral mixture it changed only slightly \from 72 to 75%) and did not depend on the M-index. The separation effectiveness for the neutyral mixture methanol-ethanol was about 22-25% lower compared to that of the positive mixture isopropyl alcohol-water.

***Key words**: rectification, surface tension, Effect of Marangoni, local efficiency*

INTRODUCTION

Surface tension is an important physical phenomenon with complex effect on the kinetics of mass transfer process. On one hand, the surface tension affects the coefficients of mass transfer while on the other hand, it exerts influence on the structure of the gas-liquid layer, mainly the bubble size [1]. The state of the interphase boundary surface strongly depends on the nature of the changes in the surface tension with the change in liquid composition. For positive mixtures (according to the classification of Zuiderweg and Harmens [2]), the highly boiling component has surface tension higher than that of the low boiling one. Studying the phenomenon by rectification, it has been established that positive mixtures form stable interphase boundary and show higher efficiencies. To describe the disturbances at the interphase boundary induced by the gradient of the surface tension, a number of experiments were carried out aiming to find explanation of the mass transfer processes taking place under the effect of Marangoni.

Hovestreijdt [3] and later Moens [4] and Zuiderweg [5**]** suggested and used the so called stabilization M-index as quantitative value in their studies on the effect of Marangoni:

$$M_{index} = \left(x - x^*\right).\frac{d\sigma}{dx} = \Delta x.\frac{d\sigma}{dx}, \qquad (1)$$

where: x – concentration of easily volatile components on the liquid phase, [mol/mol]; x* - composition of the liquid in equilibrium with the vapors leaving the tray with composition y_n, [mol/mol]; $\Delta\sigma/\Delta x$ - change of the surface tension with the change of the content of easily volatile components in the liquid phase, [N/m].

Hovestreijdt studied the effect of Marangoni on the formation of bubbles during boilking of two-component mixtures. [3]. He found a relation between the maximal heat flow and transition from nucleus boiling to boiling in an unstable layer and the stabilization M-index. There a number of methods for prediction of the efficiency coefficient on large sieve trays. Dribika and Biddulph have demonstrated this in systems where the effect of Marangoni was observed but none of these methods gives exact predictions [6].

The aim of the experiments was to obtain additional information about the influence of the effect of Marangoni on the efficiency by rectification of model mixtures methanol-ethanol and isopropyl alcohol-water. This problem draws the attention of many researchers studying the

relationship between the effect of Marangoni and the mass transfer process with the aim to summarize the results obtained and apply them in industry.

MATERIALS AND METHODS

For the experimental part of the study, a laboratory glass column with 0.045 m in diameter was used [7], equipped with extended outer weirs to eliminate the wall effect on the gas-liquid layer forming on the tray. The small diameter of the tray (32 mm) makes it correct to assume full mixing of the liquid and allows direct experimental determination of the local efficiency. All the experiments were carried out under atmospheric pressure and full phlegm, so the mole debits of both phases are equal (G = L). For the experiment, equilibrium data were used [8] to draw the equilibrium plots $y^* = f(x)$. The local efficiency E_{OG} was calculated on the basis of the experimental data obtained. All the analyses of the binary mixtures compositions were carried out refractometrically in a Abbe refratometer – AR4D equipped with thermostat. As a result from the experiments, data were obtained for the surface tensions of the two mixtures at diiferenr compositions. The M-index of both mixtures was calculated from their phase diagrams and the diagram showing the change of mixtures surface tensions depending on the composition over the whole interval of concentrations.

RESULTS AND DISCUSSION

The change of M-index of the mixture methanol-ethanol is shown in Fig.1. The values of the M-index changed in the interval $(0,02 - 0,25).10^{-3}$ N/m, with a small maximum of the M-index change in the interval 0,4 -0,7 mol/mol.

For the mixture isopropyl alcohol-water (Fig.2), the values of the M-index changed in the interval $(3,33 - 16,62).10^{-3}$ N/m with a maximum of the curve M=f(x) within the concentration interval x = 0,1 - 0,3 mol/mol. The values of the M-index for the mixture isopropyl alcohol-water were about 60-170 times higher than these for the mixture methanol-ethanol. Стойностите на M-индекса за сместа изопропилов алкохол-вода са 60 до 170 пъти по-големи от тези за сместа метанол-етанол.

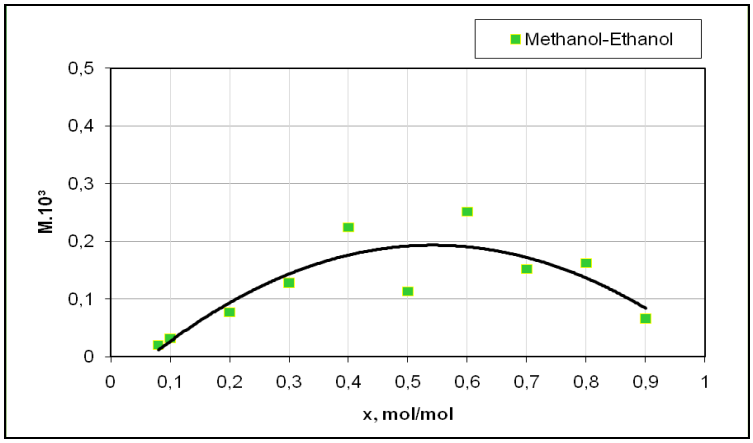

Fig.1. *Dependence of M-index on the composition of the mixture methanol-ethanol.*

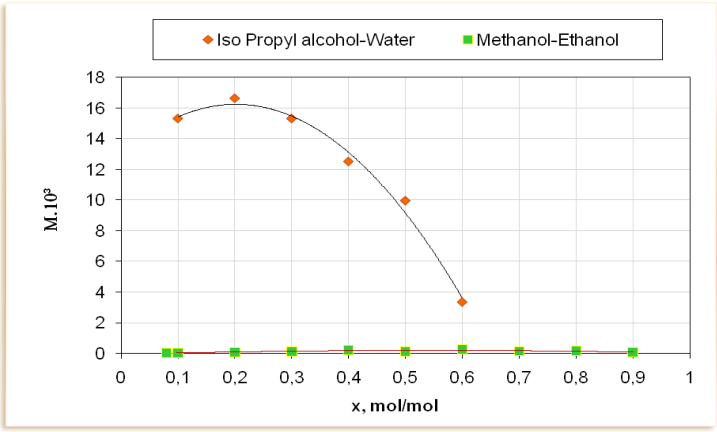

Fig.2. *Dependences of the M-idices on the compositions of the mixtures methanol-ethanol and isopropyl alcohol-water.*

An attempt was made to obtain quantitative estimation for the effect of surface tension on the local efficiency (E_{OG}). The results obtained arepresented in Fig.3 for methanol-ethanol and Fig.4 for isopropyl alcohol-water. For the mixture methanol-ethanol, the change of the M-index did not affect E_{OG}, i.e. surface tension had no effect on the degree of separation of the mixture methanol-ethanol.

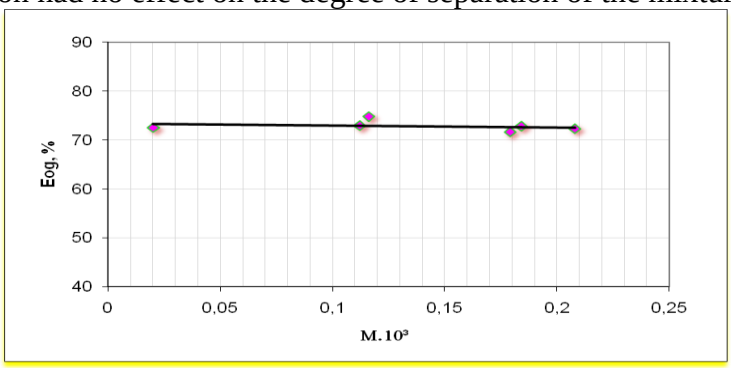

Fig.3.*Dependence of the local efficiency on M-index for the mixture methanol-ethanol*

With the increase of the M-index, the values of the local efficiency (E_{OG}) for the mixture isopropyl alcohol-water increased from 82% to 98 %. Besides, the local efficiency increase by 15-16% at M-index values in the interval from 10.10^{-3} to 14.10^{-3} but at M-index values higher than 14.10^{-3} the dependence between the change of local efficiency and the M-index remained unchanged.

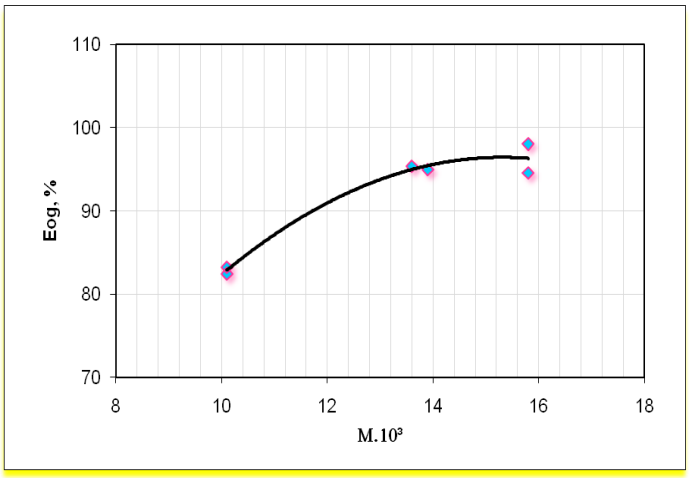

Fig.4. *Dependence of local efficiency on M-index for the mixture isopropyl alcohol-water*

CONCLUSIONS

1. The change of the stabilization index (M-index) with the change of the compositions of both mixtures was analyzed.
2. Using the experimental data on the local efficiencies (E_{OG}) of the mixtures methanol-ethanol and isopropyl alcohol-water, the influence of the surface tension was analyzed.
3. The local efficiency (E_{OG}) for the positive mixture isopropyl alcohol-water was found to increase from 82% to 98% (about 20%).
4. The local efficiency for the neutral mixture methanol-ethanol changed only slightly from 72% to 75% and did not depend on the M-index.
5. The separation effectiveness of the neutral mixture methanol-ethanol was about 22-25% lower than that of the positive mixture isopropyl alcohol-water.

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