RATIONALISATION POSSIBILITIIES OF BIOETHANOL DEHYDRATATION

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Abstract. The conventional rectification can be rationalised if various additives that enhance the process, such as calcium chloride, sodium acetate, magnesium phosphate, etc. are added to the distilled alcohol solution during this process. When specific additives are applied, it is possible to produce bioethanol through transformed rectification with a 100 % concentration, the number of plates required for the rectification columns and the height of the column decreases two times, and the consumption of energy – by 50 %.

Key words: bioethanol, rectification, additives.

Introduction

The most common technology used for bioethanol dehydratation at present includes distillation of the fermented leaven, rectification of the leaven distillate and, using molecular sieves, absorption of the water which cannot be separated by means of conventional rectification [1].

The most complicated link in this chain is alcohol rectification, which consumes most of the dehydratation energy (about 60 %). This is determined by the necessity to obtain through rectification high-concentration (96 % or 94 % mass/vol) alcohol, which is achieved by using columns with 80 and even more plates. Such columns are 20...25 m tall. The high alcohol concentration is ensured not only by the great number of plates in the column but also by the high phlegm number (F=3...5). However, the higher is the phlegm number, the higher is the consumption of energy.

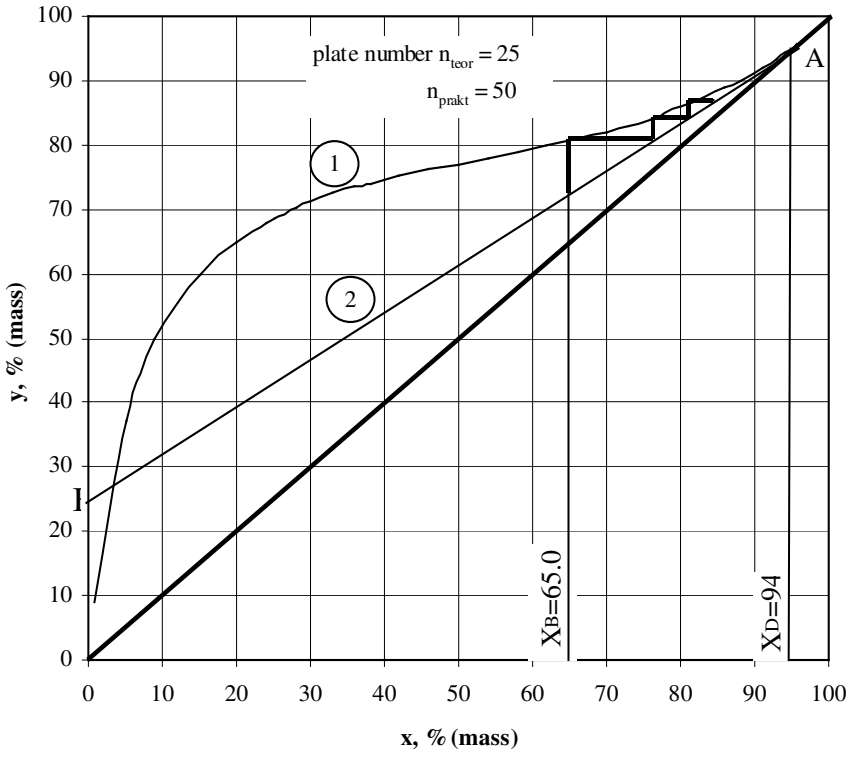

Fig. 1. **Graphical representation of the classical rectification process:** if the phlegm number F=3; the feeding concentration X_B=65.0 % (mass); the concentration of the distillate X_B=65.0 % (mass); ① – the equilibrium line; ② – the operation line

Both these concentration factors are based on the theoretical foundation of the rectification process, and they can be determined explicitly with the help of the graphic method using the equilibrium diagram. Our work is aimed at the transformation of the conventional rectification process. The efficiency of the transformation can be seen when the results are analysed in the

equilibrium diagrams. Fig. 1 presents a picture of the conventional rectification with the resultant number of plates and the phlegm number, and picture 2 is the same, only for transformed rectification.

Analysis of conventional rectification

The basis of the diagram (Fig. 1) is an equilibrium curve 1 constructed by using the data about the concentration of the boiling alcohol-water solution and the concentration of the released vapour given in the table [2]. The necessary output data – the (feeding) concentration of the leaven distillate to be introduced into the rectification column X_B=65.0 % (mass), and the (production) concentration of the discharged distillate X_D=94.0 % (mass) – are taken from the rectification practice (production).

The diagram allows determining that:

- The maximum alcohol concentration achieved in the conventional way (the aseothropic concentration) is 95.57 % (mass);
- The minimum phlegm number F_{min} is 1.85. To avoid over complication of the diagram, its defining is not shown. The real phlegm number F_{min} is obtained by multiplying it by the coefficient 1.5...2.5. If the multiplier 1.85 is chosen, then F=3.0, which is a value applied in practice;
- The theoretical number of plates n_{teor}=25; it is determined by counting the steps which can be drawn between the operation line 2 and the equilibrium curve 1. The drawing of the steps is started at the feeding concentration X_B=65.0 % (mass) and it is finished at the concentration of the distillate X_D=94.0 % (mass). Due to the small scale of the diagram it is not possible to draw in all the steps at a concentration over 90 %. The practical number of plates can be determined considering the coefficient of efficiency of the plates, which is 0.5. Guided by this, the practical number of plates would be 50. If 20...25 evaporation plates are added to them, then the total number of plates in the column will be 70...75.

The experimental part of the transformed rectification and the analysis of the process in the equilibrium diagram

The conventional rectification can be rationalised if various additives that enhance the process, such as calcium chloride, sodium acetate, magnesium phosphate, etc. are added to the distilled alcohol solution during this process. In our work we have applied various additives having a favourable effect on the rectification process [3, 4, 5].

Experiments were made using laboratory equipment where steam obtained in a steam generator was moved through the alcohol liquid with additives thus simulating the operation of two adjacent plates in the column.

The experimental results of the most effective additive are shown in Table 1.

The figures of the table were used to construct the equilibrium curve 1 shown in Fig. 2. In order to determine the characteristics of the transformed rectification column, the feeding concentration X_B=65.0 % (mass) is assumed the same as it is when the conventional rectification is analysed (Fig. 1). The final rectification concentration X_D=90.0 % (mass) is an index only for the intermediate product because concentration continues to rise reaching X_D=100 % for the end distillate.

The diagram allows determining that:

- It is possible to produce bioethanol through transformed rectification with a 100 % concentration;
- The minimum phlegm number F_{min} is 0.4. The real phlegm number F = 0.5;
- The theoretical number of plates n_{teor} = 8, the practical number n_{prakt} = 16. When adding 20…25 plates from the evaporation part, the total number of plates in the column will be 36...41.

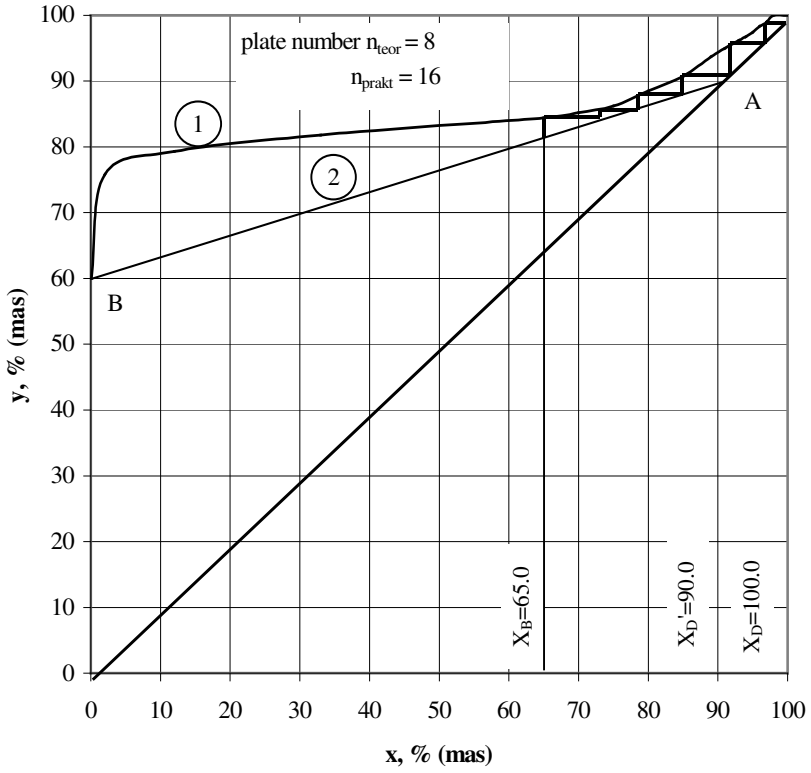

Fig. 2. **Graphical representation of the rectification process with additives:** if the phlegm number F=0.5; the feeding concentration X_B=65.0 % (mass); the final the concentration of rectification X_D'=90.0 % (mass); the concentration of the distillate X_D=100.0 %; ① – the equilibrium line; ② – the operation line

Table 1

Variations in the alcohol concentration during its distillation in the presence of additives

Vapour concentration of the alcohol introduced into the mass to be distilled, % (mass)	**Concentration of the released vapour, % (mass)**	**Theoretically prognosticated vapour concentration during its distillation without additives, % (mass)**	**Difference in concentrations [(3) – (4)], % (mass)**
100.0	100.0	100.0	0
98.0	100.0	impossible	-
97.0	99.0	impossible	-
96.0	97.8	impossible	-
95.0	97.4	95.05	+2.35
94.0	96.7	94.20	+2.50
93.0	96.2	93.40	+2.80
91.0	95.0	92.00	+3.00
89.0	93.7	90.70	+3.00
85.0	90.7	88.30	+2.40
80.0	88.5	85.80	+2.70
75.0	85.8	83.80	+2.00
70.0	85.2	82.10	+3.10
65.0	84.4	80.80	+3.60
33.0	81.8	72.00	+9.80
12.0	79.3	56.00	+23.30
2.0	75.8	20.00	+55.80
0.1	60.0	1.30	+58.70

Conclusions

The following conclusions can be made as a result of the analysis of the table and the diagrams:

1. There is no limitation on the growth of alcohol concentration in the transformed rectification which proceeds in the presence of additives, i.e. there is no aseothropic concentration;
2. The difference in concentrations between the adjacent plates in the transformed rectification is considerably greater;
3. The phlegm number in the transformed rectification is six times less, which reduces the consumption of energy for rectification by 50 %, but, if related to the entire bioethanol dehydratation chain, by 30 %;
4. The number of plates required for the column in the transformed rectification is two times less; therefore the height of the column will also be two times less.

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