EVALUATION USABILITY OF WATER ADSORPTION AND RECTIFICATION IN DEHYDRATION OF BIOETHANOL

Gunars Bremers[1], Gints Birzietis, Anita Blija[1], Arnolds Skele[1], Adolfs Rucins[1], Aleksejs Danilevics[2]
[1]Latvia University of Agriculture, [2]Latvia University
gunars.bremers@gmail.com

Abstract. At the moment the combined method – mash distillate rectification with following water adsorption by molecular sieves – is the most widely used method in bioethanol dehydration. We have estimated the energy consumption of the both water removal processes and come to the conclusion that in case of alcohol concentrations up to 90 percent rectification is more advantageous, but above this concentration – water adsorption. Combining of these processes and performing them simultaneously is even more beneficial. Then, by adding water adsorption to rectification, it is possible to gain 60 to 80 percent energy saving. These studies allow us to propose a new bioethanol dehydration technology, which we named as congruent dehydration of bioethanol.

Keywords: congruent dehydration of bioethanol, rectification, water adsorption.

Introduction

Dehydrated bioethanol is currently the most widely used method of combined – mash distillate rectification, followed water adsorption by molecular sieves [1]. This is shown schematically using flow chart in Figure 1.

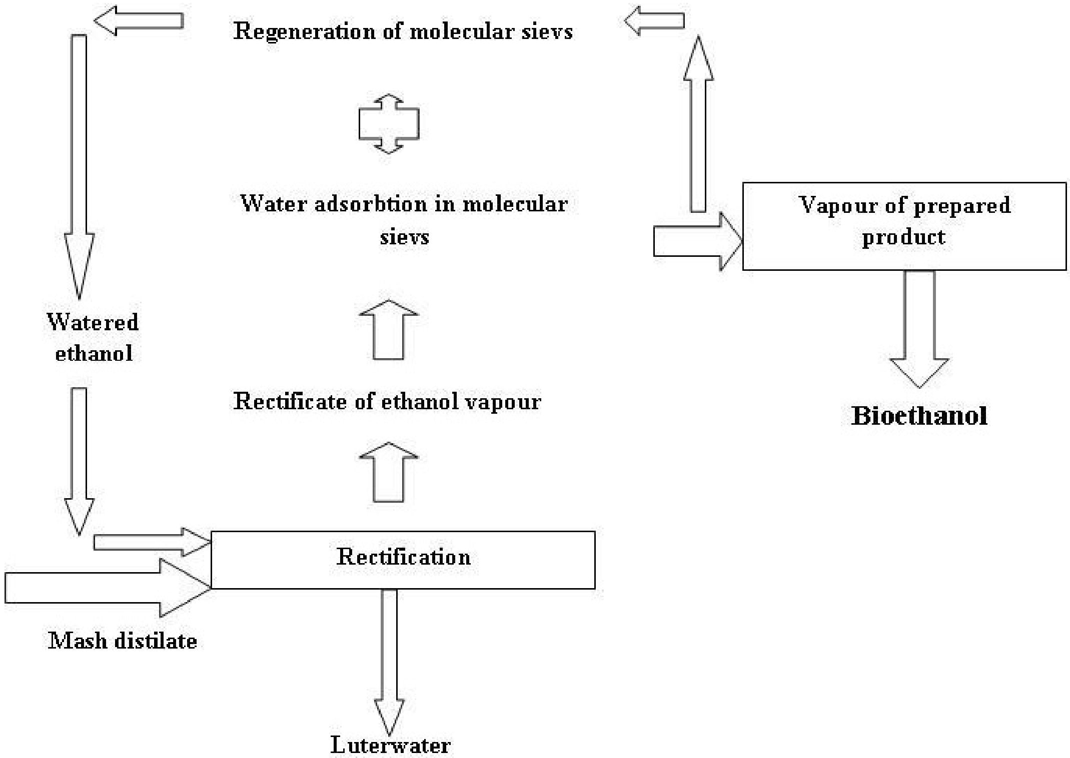

Fig. 1. **Flow chart of classical dehydration**

Rectification is based on the principle that boiling dilutes alcohol solution; it releases the steam, as the alcohol concentration is greater than it is in boiling liquid. Repeated, multiple boiling of alcohol solution and the resulting vapour condensation operation, practically makes the alcohol concentration increased to approximately 96.5 % vol (in theory it could be up to azeotrope concentration – 97.2 % vol or 95.57 % by mass). This process is called rectification of alcohol, and operates the rectification columns with plates which then are repeated boiling liquid-vapour condensation.

The bioethanol alcohol concentration must be close to 100 %. To achieve this, the rectified spirit removes the remaining water adsorbing with specific reference to the zeolite-made water-absorbent material – molecular sieves.

The issue in the so-called dehydration of bioethanol classical method can be seen in a number of shortcomings:

1. water separation in order to achieve the desired concentration of alcohol; separated into two separate stages, rectification and water adsorption;
2. rectification works in the continuous operation, but the molecular sieves can be used only for recurrent regime- after saturation of the adsorbent with water, it must be recovered, therefore it is necessary to make two molecular sieve sets of equipment;
3. in regeneration of molecular sieves, discharged from the water (about 15 % of the total water volume), comes back to the mass unit, and is again separated from the alcohol;
4. alcohol rectification process high concentrations are ineffective, and the closer azeotrope concentration, in smaller differences between the boiling solution and the steam released from the concentration [2].

In the studies, we have tried to present to the classic dehydration technology gaps prevent making another dehydration – congruent bioethanol technology. These technologies will sign “congruent” expresses that the two processes dehydration – rectifying and adsorption of water – are being implemented simultaneously, in one facility.

Test equipment and methodology

Experiments conducted in laboratory and the contact equipment Kjeldahl flask [3], and columns made of 80 mm diameter pipes that connect them to the power and steam condensation device. The contact equipment, which was filled with water adsorptive, zeolite base material, was to feed in diluted alcohol vapour, but steered dehydrated alcohol vapour, which condense, obtaining a liquid sample and was estimate the alcohol concentration. Comparing it with the power of alcohol concentration was able to judge by dehydration effect.

In the contact equipment, which was filled with the adsorbent, simultaneously both the rectification and water adsorption processes were held. The result was the sum of the two dehydration processes. These divisions separate the elements used in the theoretical rectification of liquid-vapours equilibrium tables [2].

Experimental results

Results the situation simulating in various dehydration column cross-sections shows in Table 1.

Table 1

Rectifying and the water adsorption process of impact assessment of simulated bioethanol dehydration column in different cross-sections

In crosscut boiling ethanol concentration, mass %	In crosscut educe ethanol vapour concentration mass, %	In rectification ensue ethanol vapour concentration mass, %	Increase concentration				
			Total	In recti-fying	% from total	Water adsorp-tion	% from total
69.5	81.9	81.9	12.4	12.4	100	0.0	0
81.9	89.1	87.5	7.2	5.6	78	1.6	22
89.1	93.7	90.6	4.6	1.5	32	3.1	68
93.7	96.4	94.0	2.7	0.3	12	2.4	88
96.4	100.0	96.4	3.6	0.0	0	3.6	100

Analysis of the results

As we have already shown previously [3], the water adsorbent presence not only enables to dewater overazeotrope alcohol concentrations, but also significantly effective method water withdrawal from the alcohol concentration of the solution in the area, which is close to azeotrope (above 90 %). For example, if the alcohol concentration was 69.5 % mass, with the evaporation (the process of rectifying base) could reach a concentration increase of 12.1 %, but at 93.7 %, the increase was only 0.3 %. Appreciable increase in the concentration column in addition to the ongoing cross-section gave the adsorption of water (2.4 %), which is already counted amounted to 2.7 %.

Rectification in addition to water adsorption can achieve significant energy savings. This is represented in the diagram (Figure 2). We have developed on the basis of the several authors on data given the heating steam consumption of alcohol to obtain a dekalitre rectification column, resulting in different concentrations of end products – from 88 to 96.5 % [2, 4].

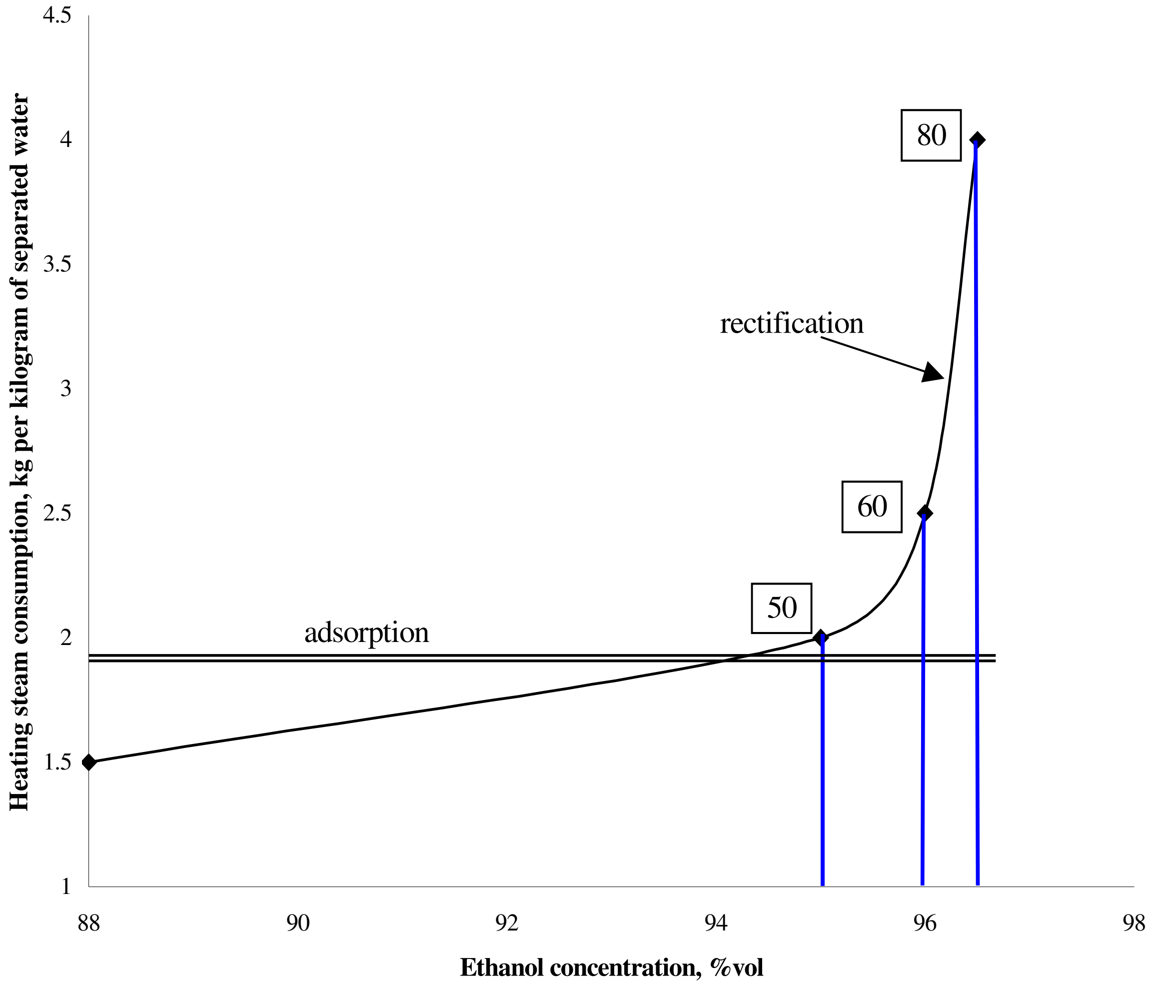

Fig. 2. **Energy consumption in rectification and water adsorption processes:**
50 – number of plates in rectification column

In the chart it is shown that the fraction of the rectified alcohol concentration increases, the energy consumption is growing rapidly, approaching the infinite consumption at azeotrope alcohol concentration. By contrast, the energy consumption of water adsorption is not dependent on the alcohol concentration. The graph also shows that the energy consumption of alcohol dehydration solution to 90 % concentration is less rectification process, whereas above this concentration of water-adsorbing.

It follows the conclusion that reducing energy consumption of bioethanol technology dehydration be built reconciling (congruenting) rectification of alcohol to water adsorption. The chart data also show that the potential energy savings can be obtained by matching the following result. In the classic dehydration bioethanol technology, in which the rectifying achieves 96.5 % alcohol concentration, one kilogram of water separating spends 4.0 kg heating steam. If congruent technology relationship between the rectification and adsorption of water be set so that up to 90 % concentration prevails rectification, while below the water adsorption, the heating steam consumption is only 1.8 kg per kilogram of separated water, that is, about 55 % less. If 15 % energy savings are added from the waste water recirculation between the molecular sieves and the rectification column (see above), the used congruent bioethanol dehydration technology can bring significant energy savings. The congruent bioethanol dehydration technology creates a basis not only for energy savings, but also simplifies the equipment design. It is known that the greater the reach of rectified alcohol concentration, the greater the number of amplifier stages (plates) in the traditional rectification column is placed [5]. This, in turn, leads to increase the tower height. Figure 2 shows that for 95 vol % alcohol concentration, the column requires 50 plates, while 96.5 % reach – now 80^{th}.

Congruent bioethanol dehydration column trays are not needed, and, through the process of improving the efficiency of the column height is lower.

Conclusions

1. The classic bioethanol dehydration technology gaps can be reduced using the congruent bioethanol dehydration technology, when both water separation processes are carried out simultaneously in a single-column machine, without plates.
2. Coincident two water separation process allows the realization of the use of the advantages of each process – alcohol concentration up to 90 % of the rectification is more economical, but higher concentrations of water-adsorption.
3. The congruent bioethanol dehydration technology economizes the energy use, and simplifies the design of the technological equipment.

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