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Simulation and Optimization of DE-Ethanizer Tower

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Abstract. Increasing need of olefins production units to ethane feed has led to produce and recover of this valuable material. In this paper, operational parameters of the DE-Ethanizer Tower of C2-C3 Recovery Unit of Bandar Imam Petrochemical Co. (BIPC) were analyzed and optimized while simulating the tower in order to achieve the best separation condition; optimization results indicate increased separation rate of both ethane and propane from this tower. Similarly, considering its nonpolar hydrocarbon feed, the different simulation aspects of DE-Ethanizer tower and Cubic Equation of State including Peng-Robinson and Soave-Redlich-Kwong equations were examined.

Keywords: DE-Ethanizer, Simulation, Optimization.

1. Introduction

Olefin Unit prepares required feed of polymer units including Low Density Poly Ethylene Unit, High Density Poly Ethylene Unit and Poly Propylene Unit. Olefin by-products are produced due to molecular breakdowns in high temperatures, for example ethane breakdown and ethylene production reactions are illustrated in eq. 1.

$$C_2H_6 \rightarrow C_2H_4 + H_2 \qquad (1)$$

As it can be seen in equation 1, light compounds, mostly ethane, consist feed of olefin unit, growing ethylene production plants has led to increasing need to ethane consumption. Although Natural Gas Fractionation Units are the main source of the produced ethane, sent streams from DE-Propanizer, DE-Ethanizer and DE-Methanizer Towers of these units to Fuel Gas System contain high levels of both ethane and propane. Separation of these compounds from the aforementioned stream has a very high economic justification and usually is conducted in C2—C3 Recovery Units. This paper deals with simulation and optimization of Recovery Unit of BIPC. Recovery Unit of BIPC is composed of two main towers namely DE-Ethanizer and DE-Methanizer; initially, feed of the unit is poured into DE-Ethanizer Tower in which ethane and methane, as overhead products, and propane and Butane, as bottom products of the towers, are separated from each other and then overhead product of DE-Ethanizer Tower enters into DE-Methanizer Tower; so methane and ethane are separated from top and bottom sides of the tower, respectively. Regarding importance of separation of light and heavy cuts in DE-Ethanizer Tower, which is the main principle to separate ethane and propane in this unit, simulation of this tower is analyzed as follows.

2. Simulation Thermodynamic

Table 1 indicates composition and specifications of input [feed] of the tower. Hysys software (Ver. 3.2) was used to simulate the tower. In each simulation process determination of a proper equation of state is very important to measure thermodynamic features such as phase balances, density, enthalpy etc. Given the feed type, a nonpolar mixture, the following equations of state are used for simulation purposes.

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Table. 1: Feed composition and property.

Composition	Mole Fraction
Co2	0.007661
Methane	0.175301
Ethane	0.538254
Propane	0.277008
i-Butane	0.001506
n-Butane	0.000231
H2s	0.000034
Cos	0.000005
Flow Rate	517.33 kmol/hr
Temperature	32 CEL.
Pressure	18.73 Kg/Cm^2 abs.
Density	27.16 Kg/M^3

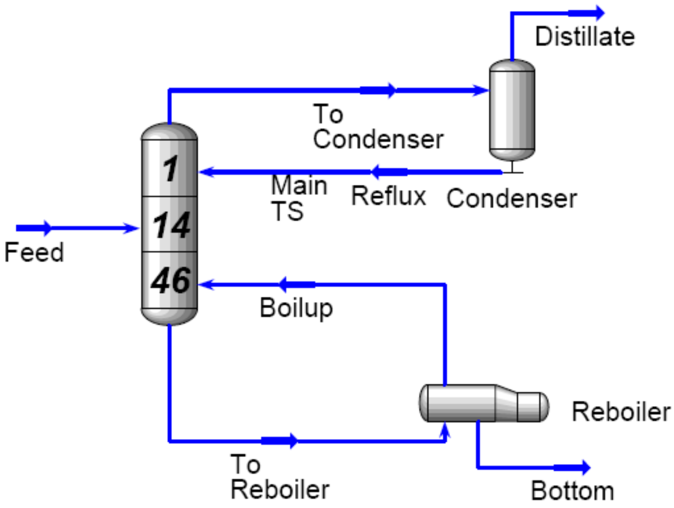


Fig. 1: Schematic of DE-Ethanizer Simulation

2.1. Peng-Robinson EoS

The Peng–Robinson EoS generally gives results in good agreement with experimental data for hydrocarbon mixtures and is widely used in the oil and gas industry [1]. The Peng–Robinson equation for pure fluids can be written as [2].

$$P = \frac{RT}{V-b} - \frac{a(T)}{V(V+b)+b(V-b)} \tag{2}$$

Where P denotes pressure, T temperature, V molar volume and R the gas constant. The temperature independent repulsive parameter b is:

$$b = 0.077796 \frac{RT_C}{P_C} \tag{3}$$

Where Tc and Pc are critical temperature and pressure, respectively. The temperature dependant attractive parameter a(T) is given by the expression:

$$a(T) = ac\left[1+m\left(1-\sqrt{\frac{T}{T_C}}\right)\right]^2 \tag{4}$$

Where

$$ac = 0.457235 \frac{RT_C}{P_C} \tag{5}$$

$$m = 0.37464 + 1.54226\omega - 0.26992\omega^2 \tag{6}$$

2.2. The SRK EoS

The explicit form of the SRK equation of state can be written as [3]

$$P = \frac{RT}{V-b} - \frac{a(T)}{V(V+b)} \tag{7}$$

Where constants a and b for pure-components are related to

$$a = 0.42747 \frac{R^2 T_C^2}{P_C} \alpha(T_r) \quad \text{And} \quad b = 0.08664 \frac{RT_C}{P_C} \tag{8}$$

And $\alpha(T_r)$ is expressed in terms of the acentric factor ω as

$$\alpha(T_r) = [1 + (0.480 + 1.574\omega - 0.176\omega^2)\left(1 - T_r^{1/2}\right)]^2 \quad (9)$$

Table. 2: Simulation Result of DE-Ethanizer

Composition	Feed	Real Condition		Simulation Result With PR EoS		Simulation Result With SRK EoS	
		Distillate	Bottom	Distillate	Bottom	Distillate	Bottom
Co2	0.007661	0.010517	0	0.010517632	0	0.010517648	0
Methane	0.175301	0.240666	0	0.240667207	0	0.240667555	0
Ethane	0.538254	0.738133	0.0022	0.738956069	5.33484E-06	0.738957686	3.86802E-06
Propane	0.277008	0.010635	0.991391	0.009810927	0.993584905	0.009809202	0.993585713
i-Butane	0.001506	0	0.005545	0	0.005544834	0	0.005544812
n-Butane	0.000231	0	0.00085	0	0.000850503	0	0.000850499
H2s	0.000034	0.000047	0	4.66778E-05	0	4.66779E-05	0
Cos	0.000005	0.000001	0.000014	1.48636E-06	1.4423E-05	1.23135E-06	1.51068E-05

3. Simulation and Result

Figure 1 shows simulation of DE-Ethanizer Unit by using both PR and SRK equations. Simulation results are summarized in table 2, which indicate a good consistency with the actual data; the sole problem is the lack of a proper estimation about level of bottom stream ethane of the tower which is accompanied with an error. In both Fluid Packages, the recovered ethane level by the tower is more than that in actual state and such low level has led to an error in ethane level of bottom stream of tower. With regard to importance of ethane and propane recovery in top and bottom sides of tower as well as analyzing different simulations by the mentioned equations of state, changes of these materials across the tower are illustrated in figure 2. As it can be seen, not only simulation results by both equations of state were very similar, but also simulation results through the tower are similar, as well.

4. Optimization of tower

Simulation of process-based units in order to optimizing them has a very long history in chemical industries, limited resources and energy preparation for different industries have cast high importance on optimization and energy integration. Simulation software's and their optimization facilities have made possible comparison of different processes in the best possible state [4]. Thermodynamic state of feed, for instance, shows us that it enters into the tower in Super Heat state, so by following PR equation of state in constant pressure, bubble point and dew point of feed are determined as -46.6°C and 10.9°C, respectively. Regarding importance of separation of ethane and propane in DE-Ethanizer Tower, all parameters are assumed constant, feed temperature is changed from bubble point level to the real temperature of the feed and then molar ratio of ethane and propane are analyzed in top and bottom of the tower. Such changes are shown in figures 3 and 4; it is observed that ethane molar ratio is enhanced near the bubble and dew points but propane molar ratio is completely descending.

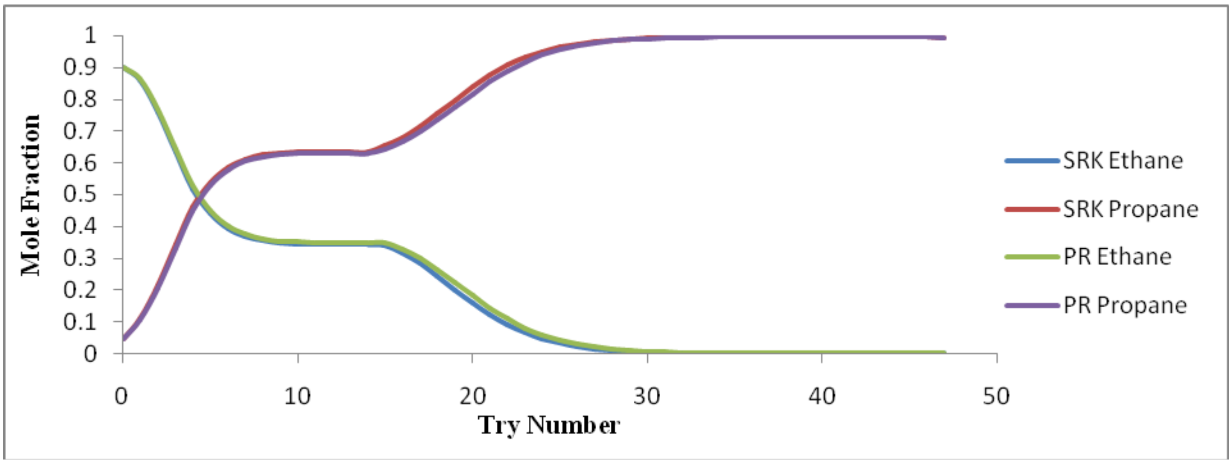
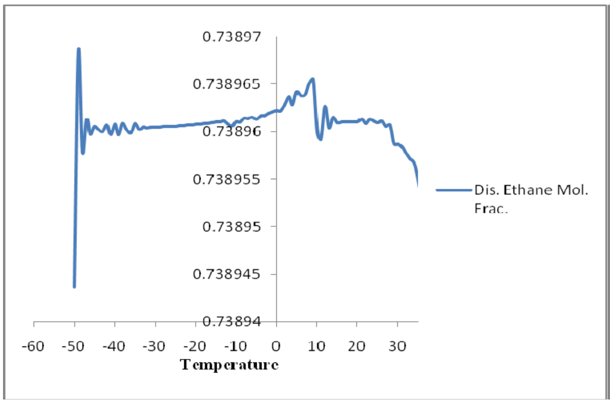


Fig. 2: Ethane and Propane Change Along the Tower



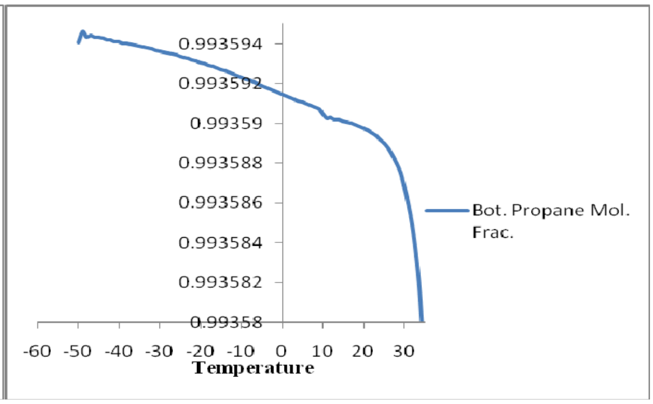


Fig. 3: Ethane Mole Fraction in Distillate Stream

Fig. 4: Propane Mole Fraction in Bottom Stream

It clearly demonstrates that increasing ethane at the top of the tower may not result in increased propane at the bottom of the tower through temperature variation. Indeed, an effective optimization entails determination of a target function which covers the best possible status and effective parameters of the function are identified too. Target function of this case study can be defined as equation 10.

B= (Ethane molar flow in Distillate stream + Propane molar flow in Bottom stream) (10)

Temperature and pressure of feed and reflux ratio of tower are some of effective parameters of the function. However, pressure effect is underestimated given its high effect on mechanical parameters of tower designing. Given dew point of feed, its temperature changes range is altered up to tower inlet real temperature and reflux ratio of tower is considered amongst 1.1 to 1.6. Subsequent to definition of target function and variables and optimization completion, figure 5 is analyzed. This 3D figure represents target function changes (B) to feed temperature and tower reflux ratio. Analyzing table of changes helps us to elicit features of optimum performance of the tower (table 3).

5. Discussion

As it was outlined previously, stimulation of chemical units is an appropriate method to optimize processes. There is a good consistency between results due to simulation of DE-Ethanizer Unit and actual data. Thermodynamic analysis of the problem showed that in operational condition of tower both PR and SRK equations showed very similar results in the conducted simulation. Feed of unit enters the tower in Super Heat state, but our findings show that in biphasic area and in particular near dew and bubble points more efficiency is expected from the tower; therefore, it was seen that decreasing temperature of feed up to 0°C can maximize the total molar flow rate of ethane in top of the tower and propane in bottom of the tower. Decreasing feed temperature is an energy-consuming process so taking final decisions about this issue depends on necessary economic evaluations. It should be so that economic efficiency of separated ethane and propane is more than the necessary costs to cool the feed which it will be analyzed in the coming studies.

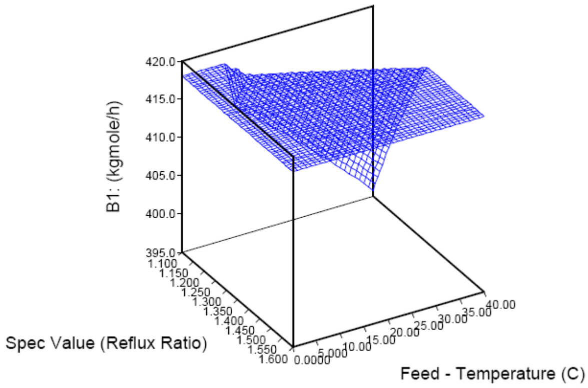


Fig. 5: Target Function Changes

Table. 3: Optimum Condition of Tower

Optimum Condition	Specification
Temperature	0
Reflux Ratio	1.368
Ethane Molar Flow +Propane Molar Flow	418.0643993

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