ORIENTAL JOURNAL OF CHEMISTRY

An International Open Free Access, Peer Reviewed Research Journal

www.orientjchem.org

Est. 1984

ISSN: 0970-020 X
CODEN: OJCHEG
2012, Vol. 28, No. (1):
Pg. 229-235

The Study of Methanol Separation Columns Control

JAFAR SADEGHI[1] and MANSUREH AHANGAR[2]

[1]Assistant Professor, University of Sistan and Baluchestan (Iran).
[2]MA Student of Chemical Engineering, University of Sistan and Baluchestan (Iran).
*Corresponding author: E-mail: jsadeghi@hamoon.usb.ac.ir

(Received: November 20, 2011; Accepted: December 30, 2011)

ABSTRACT

The design, optimization and better control of refinery processes become possible via dynamic simulation. In this article, a methanol distillation unit with three columns has been simulated to separate methanol from its impurities and water in steady and dynamic states, using commercial softwares. Moreover, it investigates, employing simulink/matlab software, the effect of variable changes on purity rate of the product methanol and water flow in the columns. This system has thermal integration property so that the condenser of the second column acts as the reboiler of the third column and these two thermal loads are considered equal in flow sheeting equation section of the commercial softwares employed. In dynamic environment, by installing level pressure controllers, the feed flow rate, product of the three columns and the purity of the product will be controlled. In spite of high number of the trays in the columns and apparently lack of need to install thermal temperature controller, the research findings show that installing temperature controllers for the columns results in high degree of separation of methanol distillation product. The findings also indicate that, with the increase of feed flow rate, the purity rate of methanol products will increase, while the purity rate of water flow will decrease. Further, the increase of feed methanol composition, though ineffective on the purity of methanol flows, it increases the rate of water flow purity. Meanwhile, the increase and reduction of the feed stage position of the first column does not affect the purity of the three product flows.

Key words: Methanol separation, Column control, Design,
Temperature controller, Dynamic simulation

INTRODUCTION

Methanol is one the most significant raw materials with a high range of use in chemical and petrochemical industries as well as dyestuff manufacturing. Methanol can undoubtedly be known as a strategic product which is used as raw material in producing other chemical compounds as well[1].

Also, regarding the predictable shortage of energy resources in the future, the direct consumption of methanol is highly remarkable as clean fuel and/or in the production of the consumption hydrogen of fuel cells. Therefore, due to the industrious significance of methanol, the study and analysis of the method of production and purification of this material will be of great importance.

'Steady state process models have long been used to assist the control engineer in designing control strategies for distillation columns. However, with the large number of industrial columns still operating in manual or with ineffectual controls, there remains a need for sound distillation column control design techniques'.[2:1]

According to Goharrokhi [3:2] 'Designing, optimizing and enjoying a better control of refinery processes become possible by means of dynamic simulation. The chemical units are never in a steady state because environment and feed disturbance, deposition of heat exchangers and the loss of the catalysts used in the process permanently influence the stable process conditions. The study of the unstable behavior of process system by employing the dynamic simulation devices is an appropriate method.'

Furthermore, the design and optimization of the chemical processes requires a careful examination of the steady and dynamic states of the unit. 'The simulations of the steady state having investigated mass and energy balance, suggest the process optimal conditions. The optimization of the process is possible through reducing the initial costs, equipment costs and manufacturing the product with a high quantity and quality. By making use of dynamic simulation, we can be sure that the ideal product is produced with easy and safe performance. In the same way, by determining the exact and detailed features of the equipments in dynamic simulation, we can examine the equipment performance in the real conditions of the unit.'[3:176]

'Parallel process units are often encountered in chemical process systems for different considerations, e.g., parallel reactors from reactor network synthesis, parallel columns for heat integration. One notable example is the feed split configuration of heat-integrated distillation column (King, 1980; Chiang and Luyben, 1983; Andrecovich and Westerberg, 1985) where the feed is split into two streams and are fed to two columns which are heat-integrated. In doing this, 50% energy saving can be achieved. We have seen extensive literature on the design and control of heat-integrated distillation systems. Tyreus and Luyben (1976) examine the control issue of double-effect distillation and an auxiliary reboiler is suggested for improved control performance. Chiang and Luyhen (1988) study the control for threedifferent heat-integration configurations: feed-split, that the light-split reverse is the most controllable light-split forward (integration), and light-split reverse. They concluded scheme. Weitz and Lewin (1996) study the same system using the disturbance cost as a controllability measure and a similar conclusion is drawn.Wang and Lee (2002) explore nonlinear PI control for binary high-purity heat-integrated columns with light splitireverse configuration. Interaction between design and control for heat-integrated and/or thermally coupled distillation systems are studied by Rix and Gelbe (2000) and Bildea and Dimian (1999) using dynamic RGA as a controllability measure.'[4: 2]

In this article, Zagros petrochemical distillation unit (unit number 300), which consists of three distillation columns, two columns of which are heat-integrated, has been simulated in steady and dynamic states by means of commercial softwares. Then, the system has been controlled in dynamic state.

Methanol Distillation Unit of Zagros Petrochemical

Methanol is one of the main chemical materials which is the base of the production of many other chemical materials. The process of methanol production is regarded as one the most complete processes in petrochemical industries because of having reformer units, synthesis and distillation.

Raw methanol as the output of the synthesis is an aqueous solution which contains heavy organic compounds such as higher alcohols and lighter compounds like DME (Di Methyl Ether) as well as unresolved gasses (H_2, N_2, CO, CO_2). This unit is divided into two sections: (a) topping section and (b) refining section. In the column of the topping section, light compounds and solved gasses are separated and in refining section, which has two columns, water and heavier compounds are removed.

The first column (T-3001) has 48 stages, the second column (T-3002) 90 stages and the third column (T-3003) 80 stages, which follow industrious scales. The columns of the refining section work under two different pressures. Column T-3002 is the column under pressure (8 bars) and column T-3003 is the atmospheric column (0.9 bars).

The input flow passes the synthesis unit and enters the 14th stage of topping column (T-3001). The output from the bottom of column T-3001enters the 70th stage of the column T-3002 and the pure methanol is separated on the top of this very column. Afterwards, the output of the bottom of the column T-3002 enters the 42th stage of the column T-3003 and finally the up and down flows of this column will be methanol and pure water products. The peripheral flow of this column will contain organic compounds and impurities. At the end, two methanol outputs will be combined on top of the columns of the refining section and will be stored in the tank.

This system has heat integration. That is, the condenser of atmospheric column acts as the reboiler of the column under pressure. This special property has been applied on the steady state simulation of the unit. The figure of distillation unit with three stage separation is presented below:

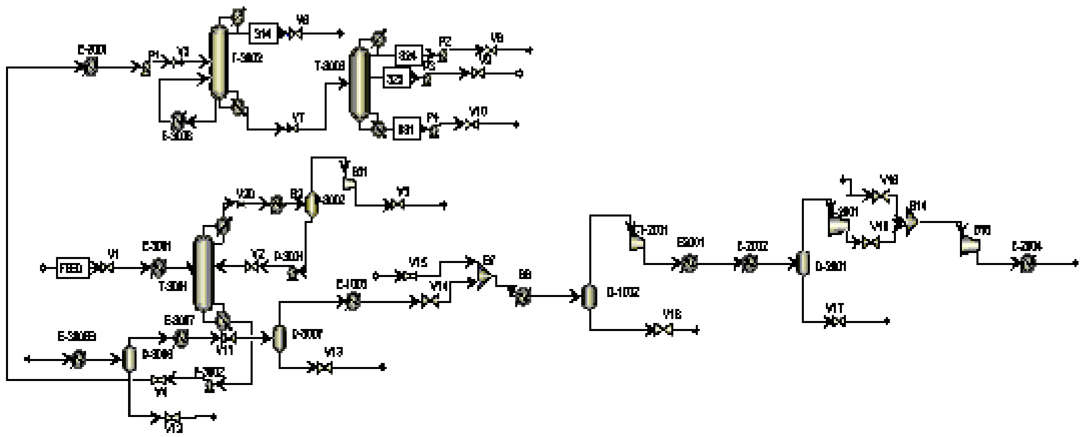


Fig. 1: Distillation unit with three column separation

Simulation in Steady and Dynamic States

To start simulation, we need to define terms such as the feed flow containing methanol, water and its accompanied impurities. Then, Peng-Robinson is chosen as the thermodynamic model and the devices and flows are placed. In steady simulation, for considering the heat integration in two columns: T-3002 and T-3003, we apply flow sheeting equation part. Thus the thermal load of the second column condenser will equal to the thermal load of the third column reboiler:

$$QC\ (T\text{-}3002) = -QR\ (T\text{-}3003)$$

After finishing the simulation in steady state, in order to make the unit dynamic, the size of the equipments of the unit such as the length and diameter of the column, the dimensions of reflux drum, and dimensions of decanter must be given. Considering the initial installation of pumps and valves in the steady simulation, to enter the dynamic environment, we start with the pressure driven option. Temperature and pressure are main variables of the distillation column because they influence the volatility of the compound components. Consequently, it is necessary to check all the time these two variables throughout the column. By entering the dynamic environment, it is observed that the software presupposes that it has installed pressure controllers for all three columns and also some level controllers. Continuing the dynamic simulation, the required controllers are installed. In this type of simulation, PID (Proportional Integral Derivative) controllers have been used and the rate of gain and the dead time related to the controllers have been regulated by Tyreus-luyben law[5]. Accordingly, the following column controllers have been designed:

Column T-3001 controllers:
PC: Pressure control with condenser thermal load regulation
LC: Level control of drum reflux with flow rate regulation of distillation product
FC: Feed flow control with valve regulation
Sump LC: Cascading level control of the base column with flow bottom product controller

Column T-3002 controllers:
PC: Pressure control with condenser thermal load regulation
LC: Cascading level control of drum reflux with reflux drum flow controller
DC: Flow rate control of distillation product with valve regulation

Column T-3003 controllers:
PC: Pressure control with condenser thermal load regulation
LC: Cascading level control of drum reflux with reflux drum flow controller
DC: Middle product flow control with valve regulation

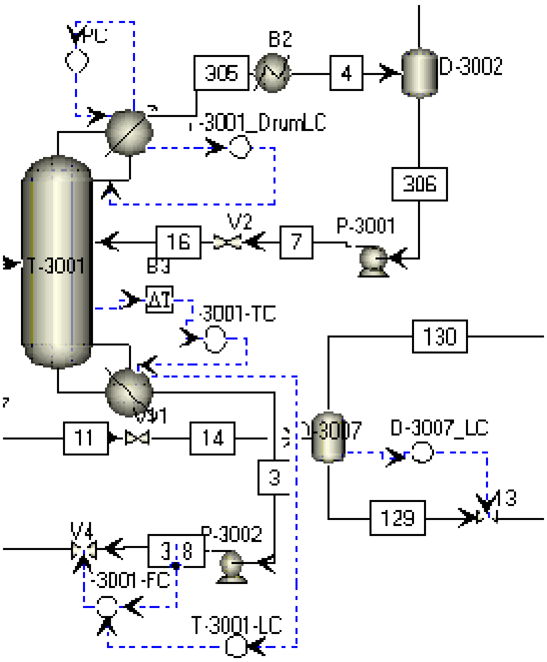


Fig. 2: Column T-3001 controllers

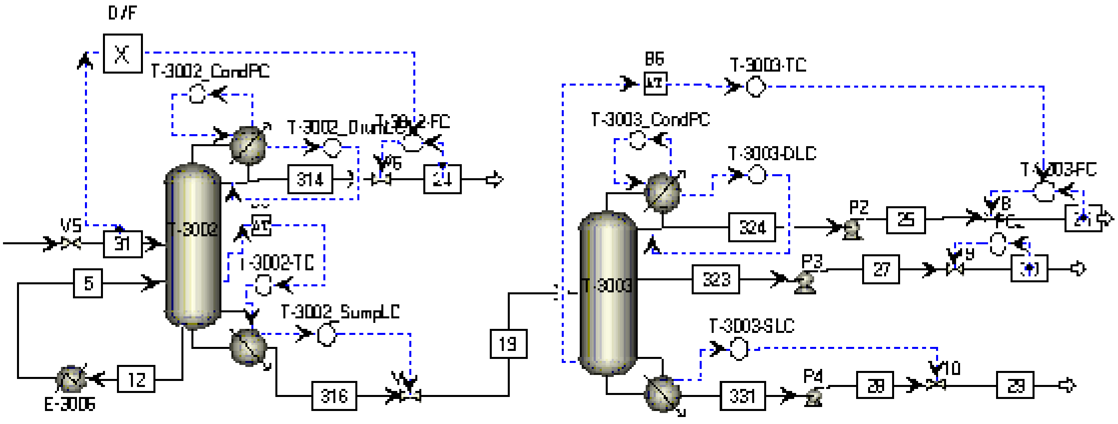


Fig. 3: Column T-3002 and T-3003 controllers

Composition controller

Carrying on the work, the control of composition of methanol was examined. The control of composition is carried out in two ways:

(a) Control of composition in the form of cascading with temperature control;

(b) Direct control of composition with reboiler Q, where this case did not operate properly for this unit.

After cascading installation of composition controller, with the help of Simulink/Matlab, the change of composition of methanol in input feed to the first column was looked into (figures 4 and 5). A 5 percent increase in composition of methanol which equals to 5 percent reduction of composition of water (of course, assuming that composition of existent impurities is trifling) compared with composition of methanol (0.6932) and composition of water (0.2948) is ineffective and the rate of purity of methanol in the third column increased (It changed from 0.9998 to 1), while the purity rate of the output water in the third column reduced from 0.999 to 0.889.

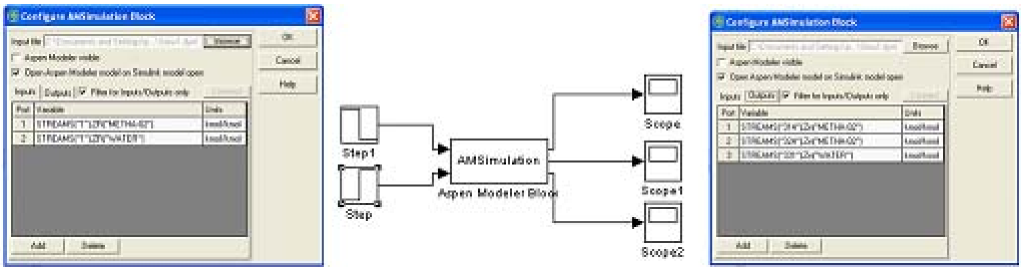


Fig. 4: Definition of inputs and outputs in Simulink/Matlab

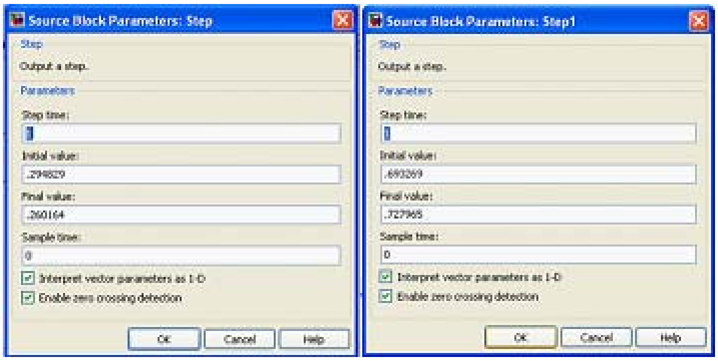


Fig. 5: A 5 percent increase of methanol composition

Tray Temperature Control

As pointed out, temperature and pressure are among significant variables of a distillation column. Due to the complexity of distillation process, these two variables have the most influence on the process control and also affect the column performance. Although this question maybe raised that despite the high number of stages of the unit there is no need to control the temperature, this subject is studied in this article.[5]

In choosing the stages required to control temperature, we make use of the steady simulation run data. Thus we draw temperature profiles of the stages. The turning-point of the diagrams determines the temperature control of each stage.

In column T-3001 the temperature of the 13th stage is controlled by reboiler Q and that of 69th stage of column T-3002 is also controlled by reboiler Q. As to the column T-3003, the temperature of its 68th stage is controlled by cascading flow rate controller of the distillation product. After the installation of these controllers and regulation of gain and integral time of each controller (figure 6), the rate of the purity changes is investigated, using the Simulink/Matlab environment. Run results of the change in feed methanol composition without temperature controller (figure 7) compared with the case with temperature controller (figure 8) show that the purity of methanol flows in T-3002 (figure 8(a)) and T-3003 (figure 8(b)) increased very trifling but the purity rate of water flow of the third column changed remarkably (figure 8(c)). Such an increase reveals the necessity of installing the temperature controller in the unit with high number of stages.

Ratio Control

Ratio controller is of significant controllers. R/F(Reflux to Feed ratio) control regulates reflux flow rate on top of the column in proportion to feed flow rate changes. Despite of suitability of R/F control in this unit, because the level control of reflux column has been carried out with reflux flow rate, it cannot be used. Therefore, D/F(Distillation product to Feed

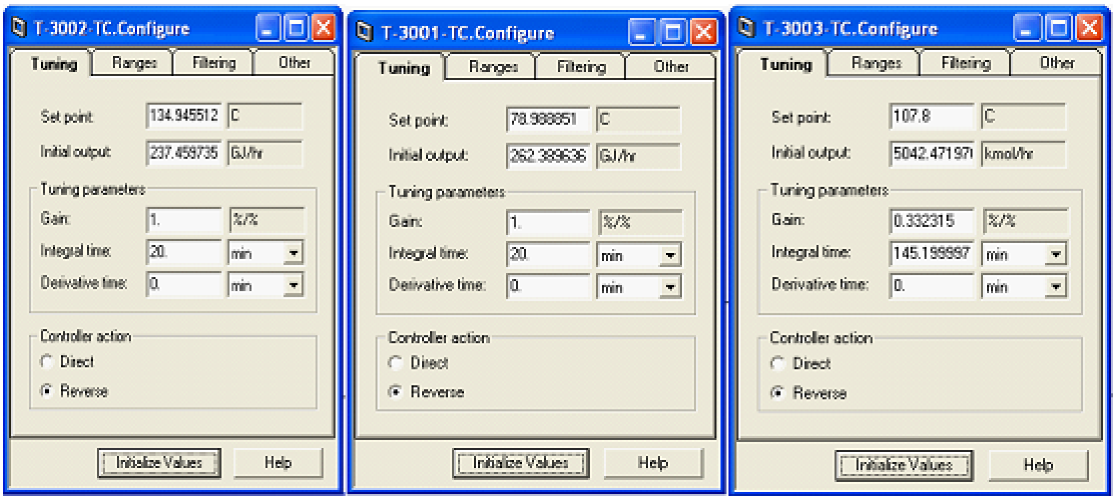
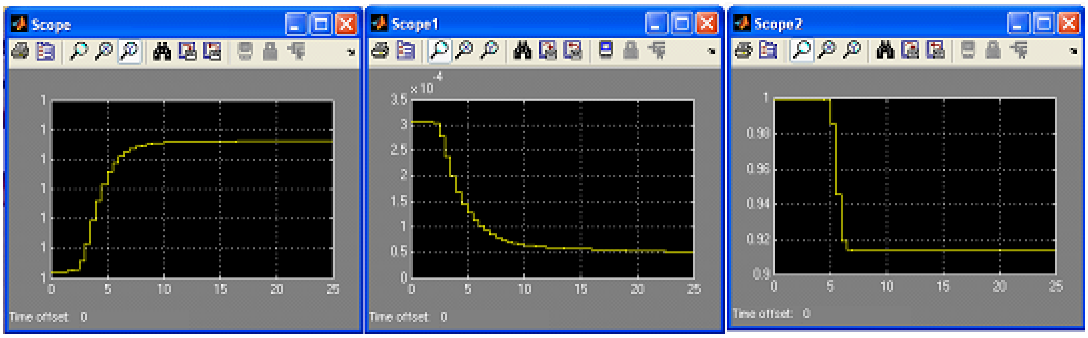
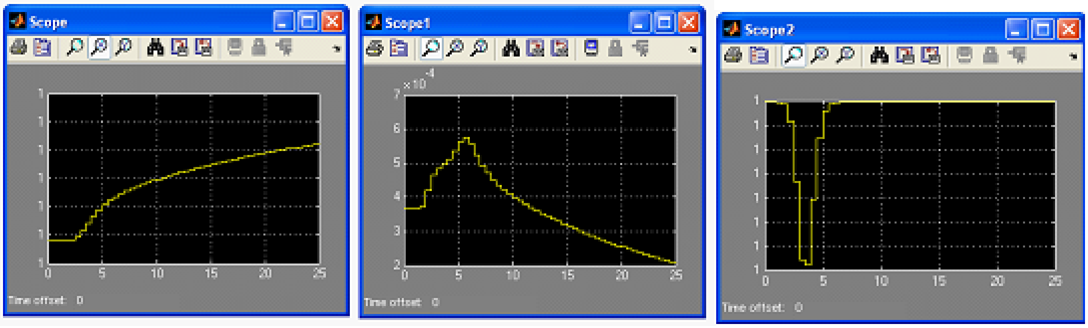


Fig. 6: Temperature controller settings



(a) (b) (c)

Fig. 7: A 5 percent increase of feed methanol composition without temperature controller



(a) (b) (c)

Fig. 8: A 5 percent increase of feed methanol composition with temperature controller

ratio) control has been employed, which is tied with flow rate controller of distillation product in cascading form. In this way, product flow rate of output methanol on the top of column T-3002 is controlled on 4500 Kmol/hr.

Conclusion

The required controllers having been installed and regulated, the effect of various variable changes on the purity of three products, namely, methanol of the second column of the flow 314, methanol of the third column of the flow 324, and water of the third column of the flow 331, were investigated. These changes have been applied in the form of 5 percent increase and 5 percent reduction in the set point rate. The examined variables were: the change of feed flow rate of column T-3001, the change of methanol composition of column T-3001, the change of stage position in column T-3001.

With an increase of feed flow rate, the purity rate of methanol flows 314 and 324 has increased and the purity rate of water flow 33 has decreased. This indicates the removal of some methanol from the bottom of the third column. To solve this problem, reboiler Q must be increased in proportion to condenser Q. Such an increase is not economic. The reduction of feed flow rate gave a cause to an increase in the purity of output water from the third column while it did not affect the purity of methanol flows.

After installing the temperature controller,the increase of feed methanol composition has been ineffective on the purity of methanol flows but it has increased the rate of water flow purity. The reduction of feed methanol composition decreased the purity of the methanol of the third column whereas it increased the purity of water flow.

The increase and reduction of the feed stage position of the first column did not have any effect on the purity of the three product flows. This was because of the high number of the stages of the unit. But as discussed, the high number of the stages does not mean that the unit is needless of temperature controller installation. After the dynamic run and the investigation of product flows, we got a high rate of methanol and water purity. This denotes the ideal effect of the temperature controller on the better performance of the unit. This case results from the fact that with an increase in the number of stages, the temperature controller will have more time for correction and regulation. While the fewer the number of stages are, the more dynamic deviation will be.

The last important result of the present article is to emphasize on the temperature controller installation, even in systems with high number of stages. Since this will be a central factor in saving energy and reducing the thermal load of the columns as well as decreasing the costs.

REFERENCES

1. E.Fielder, G.Grossmann, B.Weiss, C.Writte, Ullmann's Encyclopediia of Industrial Chemistry, A16 (1990).
2. Paul S.Fruehauf, Donald P.Mahoney, Distillation Column Control Design Using Steady State models: Usefulness And Limitations, ISA Transactions, **32**(2): pages 157-175 (1993).
3. Mahdi, Goharrokhi, Dynamic Simulation of Chemical Process Using Hysys, Daneshgaran Sanat Pazhuh Company, Tehran, 1387
4. W-H.Tsai, H-P.Huang, C-C.Yu, Control Structure Design For Parallel Processes, Aplication to Heat-Integrated Distillation, Chemical Engineering Research And Design, **83**(2): 153-159 (2005)
5. William L., Luyben, Distillation Design and Control Using Aspen^{tm} Simulation, John Wiley & Sons, Inc., Hoboken, New Jersy (2006).