5th National Conference on New Researches in
Chemistry and Chemical Engineering
Tehran-2019

Economic Comparison between Membrane and Adsorption Processes for Separation of CO_2 and CH_4 Mixture

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ABSTRACT

In this work, the economic comparison between a pressure swing adsorption (PSA) process and a membrane unit for removal of carbon dioxide from a carbon dioxide/methane mixture was studied. The adsorption process for the adsorbent of zeolite 13X and the membrane unit for membrane of 6FDA TAPDO was studied.

First, the calculation of TAC for membrane unit with the five prices of membrane including 20$/m^2, 50$/m^2, 100$/m^2, 150$/m^2 and 200$/m^2 was done and the best pressure for every price of membrane with minimum of TAC was selected. Then, the PSA process was investigated for the adsorbent of Zeolite 13X in the two pressure of 10 bar and 15 bar. All the simulations of PSA (includes 4 beds and 8 steps) were done in the Aspen Adsorption v8.8 and the membrane process was simulated in the Matlab.

For pressure of 15 bar and membrane price of 100$/m^2, the results showed that the TAC for PSA unit is 12% less than the TAC for membrane unit in spite of that the mole fraction of CO_2 in the product for PSA unit is 0.0001 and for membrane unit is 0.017. The cost of membrane unit and adsorption unit is mostly related to the compressor and electricity costs, and also the adsorbent cost is almost 2% of PSA process TAC while the membrane cost is more than 20% of membrane process TAC.

Keywords: Membrane, Adsorption, Carbon dioxide, Separation.

1. INTRODUCTION

The CO_2 removal is an important process in industries such as transportation of natural gas through pipelines in order to avoid the corrosion problem. Several methods have been studied and implemented for the separation of CO_2 from CH_4 including: Absorption , cryogenic distillation, membrane processes and adsorption [1].

Pressure swing adsorption of methane, carbon dioxide on zeolite 13X was studied in many works [2], [3] and the membrane process was used to removal CO_2 from natural gas and flue gas [4]–[6].

2. MODELING AND SIMULATION

In this work, the membrane unit and PSA system was simulated in Matlab and Aspen Adsorption, respectively. The feed flow rate is 0.1 m^3/s and the mole fraction of methane in the feed stream is 0.75, and also the feed temperature is 300 K which are all constant in all the PSA and membrane unit cases studies.

2.1 Modeling of Membrane Unit

A hollow fiber membrane unit with concurrent flow arrangement shown schematically in Fig. 1 is selected for the CH_4 and CO_2 mixture separation. The membrane unit is divided into n elements and following assumptions are made including:

- **Steady state process**
- **Ideal gas behavior**
- **Isothermal operation**
- **Negligible pressure drop**
- **Plug flow along the membrane**
- **Negligible deformation of the membrane under pressure.**