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# Compact Flat-Box Adsorbers for Air Separation by PSA Processes

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**Summary**

Cylindrical adsorbers are usually used for pressure swing adsorption (PSA) processes. In this study, the flat-box adsorbers which stack together replaced the traditional cylindrical adsorbers. Simulation was performed for separation of air (21% oxygen; 79% nitrogen) in Skarstrom cycle. Instantaneous equilibrium between solid and gas phase with non-isothermal operation were assumed and the bed pressure drop could be neglected. The adsorption isotherms used were extend Langmuir isotherms and 5A zeolite was utilized as adsorbent. In addition, to verify the applicability of the simulation program on the system of air separation with 5A zeolite, the simulation results of the cylindrical adsorbers were compared with the experimental data in literature. The simulation results were in good agreement with experimental data obtained elsewhere, and showed the reliability of this PSA simulation program. The simulation results of flat-box adsorbers and traditional cylindrical adsorbers were compared. The performance of the flat-box adsorbers was better than that of the traditional cylindrical adsorbers when the heat transfer coefficent between neighboring adsorbors was very high. The effects of operating variables such as step time, adsorption pressure, the heat transfer coefficient between neighboring adsorbers were investigated on the performance of PSA.

**Keyword:** pressure swing adsorption(PSA); flat-box adsorber; air separation

**Extended Abstract**

Pressure swing adsorption (PSA) is a cyclic process for separation of gas mixtures. In the previous study of Zhou et al.[2], a new compact design of PSA has been employed. All columns of the PSA process were reduced to disks that were stacked together. The feasibility and performance of this new design were tested with a four-bed process experiment. However in their experiments, only experiments with stacked-disk adsorbers were performed. No comparison between stacked-disk adsorbers and conventional packed-bed adsorbers were made. In our study, PSA simulations are performed to compare the performance between new compact flat-box adsorbers and conventional packed-bed adsorbers. The PSA process for producing oxygen from air by utilizing zeolite5A as adsorbent is studied.

The new design of compact flat-box adsorbers which are stacked together are expected to reach higher performance of PSA by letting the released heat from the adsorption bed be transferred to the desorption bed. The Skarstrom cycle is chosen as case study, because when one bed is operating on adsorption step, the neighboring bed is operating on desorption step.

Under the same operation conditions as Farooq et al.[3], our simulation results is showed in Table 1. As the heat transfer coefficient between neighboring adsorbers increases from 14.049 to 100 J/K-m$^2$-s, the oxygen purity in product from air doesn't become better beyond all expectations. The cause of this effect is that the desorbed oxygen amount at production step for Run 1 being similar to that of Run 2. At the same time , feed ratio of Run 2 to Run 1 is close to the ratio of adsorbed nitrogen amount of Run 2 to Run 1, shown in Table 2. Consequently, the oxygen purity in product for Run 1 is higher than that of Run 2.

As the heat transfer coefficient between neighboring adsorbers increases from 14.049 to 1000 J/K-m$^2$-s, the oxygen purity in product from air becomes better. The cause of this effect is that the adsorbed nitrogen amount at production step for Run 3 is more than that of Run 1, and the desorbed oxygen amount at production step for Run 3 is more than that of Run 1. Although the feed amount of Run 1 is less than that of Run 3, purity of Run 3 is better than that of Run 1.

The effects of operating variables such as step time, bed length are investigated on the performance of the PSA process with compact flat-box adsorbers. Decreasing the 1st and 3rd step time can increase the product flow rate. Increasing the 2nd and 4th step time can increase the amount of product per cycle, but the product flow rate and the oxygen purity in product from air decreases. With increasing bed length, the oxygen purity in product increases.

Table 1. Simulation results of the flat-box adsorbers and comporision with cylindrical adsorbers

| | Cylindrical adsorbers | Flat-box adsorbers | | |
|---|---|---|---|---|
| | | Run 1 | Run 2 | Run 3 |
| Heat Transfer Coefficient Between Neighboring Adsorbers [ J/K-cm$^2$-s] | - | 1.4049E+01 | 1.0000E+02 | 1.0000E+03 |
| Product to Feed Ratio | 5.93% | | | |
| Purge to Feed Ratio | 16.46% | | | |
| Average Feed Flow Rate [ L/min at STP ] | 3.6918 | 3.7452 | 4.1102 | 4.6822 |
| Average Product Flow Rate [ L/min at STP ] | 0.2189 | 0.2220 | 0.2437 | 0.2777 |
| Purity | 94.46% | 94.22% | 93.18% | 95.13% |
| Recovery | 26.68% | 26.60% | 26.31% | 26.87% |

Table 2. Effect of heat transfer coefficient between neighboring adsorbers of flat-box adsorbers at production step

| | Run 1 | Run 2 | Run 3 |
|---|---|---|---|
| The Amount of Feed [L at STP] | 1.5462 | 1.8273 | 2.0796 |
| Ratio with Respect to Run 1 | - | 118.18% | 134.50% |
| The Oxygen Amount of Desortion [L at STP] | 0.6005 | 0.6192 | 0.7314 |
| Ratio with Respect to Run 1 | - | 103.12% | 121.81% |
| The Nitrogen Amount of Adsortion [L at STP] | 1.0358 | 1.2241 | 1.4131 |
| Ratio with Respect to Run 1 | - | 118.18% | 136.42% |

**References**


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2 Zhou, L., Ouyang, X.F., Li, W., Li, S., and Zhou, Y., (2006), *Separation Science and Technology*, 41, 247-259

3 Farooq, S., and Ruthven, D. M., (1990), *Chemical Engineering Science*, 45, 107-115