International Journal of Research and Review
www.gkpublication.in E-ISSN: 2349-9788; P-ISSN: 2454-2237

Review Article

Pressure Swing Adsorption: A Summary on Investigations in Recent Past

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Received: 25/09/2016 *Revised: 17/10/2016* *Accepted: 17/10/2016*

ABSTRACT

Purification of gases in the chemical industries is ever evolving field in terms of clean technology and cost effectiveness. The flue gases need to be treated for removal of particulate matter (PM), gases like oxides of sulfur, carbon and metals. This can be done by adsorption, bag filters, cyclones (PM), absorption etc. Adsorption is also very effective for this treatment. Also adsorption finds application of cleaning air for instrumentation and process applications. The regeneration of adsorbents and recovery of valuable gases is an important aspect of the adsorptive separation. Temperature and pressure swing (TSA and PSA) adsorption uses change in temperature and pressure respectively for regeneration. Current review summarizes research and studies on PSA, as it is widely used technique.

Key words: Regeneration, recovery, vacuum, recovery, purity.

INTRODUCTION

Separation of impurities from gases and liquids can be carried out by various unit operations. The liquid liquid separation can be carried out by extraction and distillation. The gases can be separated by gas absorption and adsorption. The recovery of many gases such as hydrogen and oxides of many metals can be carried out by sorption method. Adsorption finds wide application in waste treatment for water and flue gas treatment. The removal of organic matter can be carried out very effectively using adsorption. [1-3]

The chemical oxygen demand can be reduced by 90 to 98 percent by using adsorption. Use of low cost material makes adsorption more attractive method. Though other methods like pervaporation and membrane treatment can be also used as advanced treatment techniques, most of the investigators have found adsorption as most convenient and effective method. [4-6] Low cost adsorbent methods were also used effectively for phenol removal. [7,8] Treatments for chromium, iron and oxalic acid removal were also effectively carried out by low cost adsorbent. [9] Removal of heavy metals like cadmium, chromium and copper were also reported by some investigators. [10-15] The treatment of flue gases is important as the gas mixture may contain valuable gases. Also removal of harmful gases from the flue gases is required from regulatory and health perspectives. The adsorption and ion exchange technologies have been effectively used from removal of sulphur dioxide, hydrogen sulphide and many other harmful gases. [16-19] Also desorption studies for various adsorbents are reported by various investigators. [20]

The regeneration of the adsorbent bed is important from economical perspectives. Various methods such as electrical and chemical regeneration are available. The adsorption for gases is normally carried out with temperature and pressure swing methods. In these methods the bed is regenerated at high temperature or very low pressure. Temperature swing adsorption is time consuming and energy intensive method. PSA is more widely used method. The current review summarizes research and studies on pressure swing adsorption (PSA).

PRESSURE SWING ADSORPTION: AN INSIGHT INTO RESEARCH AND STUDIES

Bessho investigated advanced pressure swing adsorption system with fiber sorbents for hydrogen recovery. [21] He analyzed mass transfer processes in the fiber sorbent module for hydrogen recovery and compared with results for an equivalent size packed bed with identical diameter and length. The model indicated the advantages of application of fiber sorbent module over packed bed technology. Chowdhury and Sarkar investigated pressure swing adsorption cycle in the quest of production of oxygen and nitrogen. [22] According to them in cryogenic engineering separating a gas mixture or removing undesirable components from a gas stream is a common problem. They presented the various aspects of PSA system towards production of pure oxygen and nitrogen. According to their discussion, the control of flow rate or step time of each step is a key factor in producing high-purity oxygen or nitrogen gas with a high productivity rate. Diffusion increases with increase in temperature. The PSA process is more suitable for rapid cycling than TSA process because of its fast nature.

Pirngruber et.al investigated vacuum swing adsorption with zeolite for post-combustion CO_2 capture. [23] According to them, technologies based on amine solvents have the disadvantage of energy consumption. The most common zeolite used is NaX which has a very strong affinity for CO_2. It is difficult to regenerate it. Also it is very sensitive to the presence of water in the flue gas. They carried out breakthrough experiments with dry and wet flue models. For both, they got 90 and 95 percentage recovery. Very low pressure requirement is limiting factor for this process. Xia et.al carried out an investigation to study pressure swing adsorption for removal of C^{+}_{2} from natural gas. [24] They observed that desorption vacuum was in direct proportion to desorption volume. They observed that the productivity tends to rise slowly with the extension of adsorption time. They also observed that the content of C^{+}_{2} decreases with the degree of desorption vacuum.

Shirsat et.al elaborated the process design methodology for the evaluation of the distillation systems. [25] They considered economic, exergetic and environmental aspects while designing. According to them, the pressure swing distillation sequence (PSDS) reduces greenhouse gas (GHG) emissions. According to their studies the exergy analysis can predict the results of the economic and environmental evaluation associated with the process design. Pressure swing adsorption (PSA) and recent advances in PSA were studied by Grande. [26] Air separation, gas drying, and hydrogen purification separation are few important areas of application of PSA. In his studies, he provided an overview of the fundamentals of PSA process while focusing specifically on different innovative engineering approaches. The fundamental of CO_2 absorption technique was use of sequential valve arrangement. He explained four steps in “Skarstrom cycle” namely feed, blow down (or evacuation), purge and pressurization. According to him, one of the major problems with PSA to introduce this technology in several fields of industries is the great flexibility of PSA is normally associated to process complexity.

Kierzkowska-pawlak and Chacuk carried out investigation on pressure swing absorption of carbon dioxide in Dmepeg solutions. [27] They determined the desorption rate based on the measured values of pressure changes. They compared desorption rate with the absorption rate at the same driving force. They used the measured overall and the diffusive desorption rates for determination of volumetric mass transfer coefficients. Their investigation indicated that, the CO_2 desorption rate increases with an increase of the stirring speed and super saturation of the solution. Diffusive desorption was observed to be slower than the desorption rate under bubbling conditions.

CONCLUSION

The regeneration of the adsorbent bed is important from economical perspectives. Various methods such as electrical and chemical regeneration are available. The adsorption for gases is normally carried out with temperature and pressure swing methods. In these methods the bed is regenerated at high temperature or very low pressure. Temperature and pressure swing (TSA and PSA) adsorption uses change in temperature and pressure respectively for regeneration. In current review, research and studies on PSA are summarized, as it is widely used technique.

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How to cite this article: Kulkarni SJ. Pressure swing adsorption: a summary on investigations in recent past. Int J Res Rev. 2016; 3(10):46-49.

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