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

Review Article

Research and Studies on Membrane Reactors

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Received: 07/06/2016 *Revised: 22/06/2016* *Accepted: 22/06/2016*

ABSTRACT

Cost effective technology with compact equipment size is always advantage in process selection. The available technologies can be modified to make them more and more cost effective. Process intensification is one such field which aims at increasing effectiveness of processes in terms of cost, space, efficiency and conversion. Coupling of two unit operations or processes can exhibit excellent results in some processes. Combination of membrane separation with reaction is found to be very effective in many applications. The membrane bioreactors find application in dehydrogenation, hydrolysis and enzyme catalyzed reactions. Current review summarizes studies and research on membrane reactors and membrane bioreactors (MBRs).

Key words: Membranes, dehydrogenation, hydrolysis, enzyme, desorption, performance, analysis.

INTRODUCTION

Chemical processes include reactions and unit operations such as extraction, distillation, leaching, crystallization, drying, humidification and dehumidification etc. The unit operations are used to isolate raw material or for concentrating the final product. The reactors and separators need considerable space and cost. Process intensification includes modifying current technology and combining two processes in order to save cost, time and space. Process intensification by using hydrotropy and cavitation has been investigated. [1-7] Advanced methods such as pervaporation, membrane bioreactors are being used in combination for more effective reaction and separation. [8-10] The results of these investigations are very promising. The reactions such as esterification can be combined with separation to yield effective results. Reactive adsorption, reactive chromatography, reactive extraction, solar distillation, pervaporation and reactive distillation are few processes which combines unit operation with reactions. [11-14] The immediate separation of product helps in shifting the reaction towards right. Also the savings of equipment cost and space are attractive attributes of these processes. This method needs proper and effective control mechanisms. The combination of membrane separation with reaction is one such concept. The current review summarizes research and studies on membrane bioreactors.

RESEARCH AND STUDIES ON MEMBRANE REACTORS

McLeary et.al discussed films and membranes based on zeolites. [15] According to them integration of reaction and separation has received attention in last 40 years. The combination results in more compact and less energy intensive processes. It is necessary to apply new techniques for manufacturing light, thin, high flux, defect-free zeolite membranes. The zeolite membranes are useful in oxidative dehydrogenation. Chibane and Djellouli carried out methane steam reforming reaction in packed bed membrane reactor. [16] They studied pd-membrane reactor for the reaction of steam reforming of methane. They developed an isothermal steady-state model to simulate the operating parameters. In their studies, they found that the conversion of methane was significantly enhanced by the removal of hydrogen from the reaction side. They observed that the performance was characterized by conversion of 50-71 percent at 500^{o}C. 92 percent conversion was achieved at 600^{o}C.

Silva et.al carried out an investigation on biogas reforming in a membrane reactor. [17] In their investigation, they evaluated syngas and hydrogen production by methane reforming of a biogas. They used carbon dioxide in fixed bed reactor for this. They observed that with hydrogen permeation, the yield doubled and also the conversion reached to 83 percent. Silva et.al carried out an investigation on optimization of membrane reactor for hydrogen production. [18] They used simulations to evaluate the influence of different parameters. These parameters include inlet reactor pressure, methane feed flow rate, sweep gas flow rate, external reactor temperature and steam to methane feed flow ratio. They observed that preliminary optimized values were in agreement with the parametric analysis accomplished with the full model.

Knezevic and Obradovic carried out an investigation on lipase immobilization. [19] They used hollow fibre membrane reactor. In their investigation, they carried out experiments to study kinetic characterization and application for palm oil hydrolysis. They observed that one-substrate first-order reversible kinetics was followed by reaction. They also observed that final conversions were higher with immobilization. Also they found that loss of activity because of enzyme desorption had little effect on the reactor stability and oil hydrolysis. Neomagus et.al carried out an investigation on catalytic combustion of natural gas. [20] They used a membrane reactor with separate feed of reactants. Their work provided an experimental and modeling analysis of the performance of a membrane reactor. They studied effect of parameters like temperature; methane feed concentration, pressure difference applied over the membrane, type and amount of catalyst deposited, time of operation on reactor performance. Easy controllability, less thermal runaways and absence of slip are advantages of a membrane reactor with separate feed of reactants.

Prieto et.al used a cyclic batch membrane reactor for hydrolysis. [21] They undertook the production of reduced-antigenicity whey protein hydrolysates. The process undertook in three steps, namely hydrolysis, ultra filtration and enzyme recycling. These processes were repeated number of times. By using the developed model, it was possible to save up to 59 percent enzyme. Li et.al carried out non-oxidative conversion of methane. [22] They studied non-oxidative conversion of methane in membrane bioreactor and effect of hydrogen removal and catalytic sites. Triwahyono et.al carried out studies on membrane reactor for epoxidation of propylene to propylene oxide. [23] They carried out studies on membrane reactor immobilized with cesium-silver (Cs-Ag) catalysts. They proposed the Langmuir-Hinshelwood model equation based on two different active sites adsorption.

Buscio et.al carried out investigation on photocatalytic membrane reactor. [24] Their studies and experiments were directed towards the Removal of C.I. disperse Red 73. They investigated a heterogeneous photocatalytic process combined with microfiltration for removal of C.I. Disperse Red 73 from synthetic textile effluents. They used the titanium dioxide (TiO_2) Aeroxide P25 as photocatalyst. They were able to achieve 60% and 90% of dye degradation and up to 98% chemical oxygen demand (COD) removal.

Shao et.al carried out investigation on performance evaluation of ceramic membrane reactor with high oxygen permeability. [25] They used Ba0: 5Sr0: 5 Co0: 8Fe0: 2O3 - (BSCFO) ceramic membrane. They observed that the material was had excellent phase reversibility. Bottino et.al studied polymeric and ceramic membranes in three-phase catalytic membrane reactors. [26] They carried out the hydrogenation of methylenecyclohexane. They reported Preliminary data on reactivity. They also observed that the addition of PVP to PVDF solution increases the amount of palladium in the final membranes.

CONCLUSION

Membrane bioreactors are gaining importance because of their advantages such as less space requirement, high yield and cost effectiveness. This combination (MBR) results in more compact and less energy intensive processes. The reactions such as oxidative dehydrogenation, steam reforming, heterogeneous photocatalytic reactions, epoxidation of propylene, biogases reforming etc. have been carried out in membrane bioreactors by many investigators.

It has been observed that MBRs yielded more effective results for the processes than conventional pathways. It can be concluded that MBRs can replace conventional reactors and separators in many processes to make them more effective in terms of cost, space, yield and conversion.

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How to cite this article: Kulkarni SJ. Research and studies on membrane reactors. Int J Res Rev. 2016; 3(6):59-62.

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