Reactor Design and Scale-up for CO_2-free Manufacturing, CO_2 Capture and Utilization.

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Highlights

- Catalytic Partial Oxidations to produce olefins can lead to reduced CO2 footprint.
- Joule heated modular reactor concepts to produce H2 and syngas are discussed.
- A novel contactor for reducing the direct air capture (DAC) of CO2 is presented.
- Reactor concepts for CO2 utilization are discussed.

The main goal of this talk is to review our recent and current collaborative efforts with local industry on the design and scale-up of reactors for CO2-free manufacturing of basic chemicals.

In the first part of this work, we discuss autothermal reactor concepts for catalytic partial oxidation of hydrocarbons using two specific cases. The first case is that of Oxidative Coupling of Methane (OCM) for which the adiabatic temperature rise is very high (900 to 1200 K) and it is impractical to design a multi-tube reactor with heat removal. We show that autothermal operation is possible with shallow-bed or "pancake-reactor" for practical range of methane to oxygen ratios even with some heat loss. We review recent laboratory and pilot scale experimental results and examine the selectivity of C_2 products on the ignited branches [1-3]. The second example is that of an oxidative dehydrogenation of ethane (ODHE) with moderate adiabatic temperature rise (200 to 400 K). For this case, we compare the traditional cooled multi-tubular reactor design (with high inlet feed temperature and near isothermal operation) with that of an autothermal reactor with ambient feed with no heat removal and near adiabatic operation [4]. We demonstrate the advantages of AO, especially for highly active catalysts. We also briefly discuss the feasibility of high temperature ODHE in which the catalytic, homogeneous oxidation and thermal cracking reactions occur simultaneously.

In the second part of this talk, we present and analyze various novel modular reactor configurations with electrical resistance heating for conducting endothermic reactions such as cracking and steam reforming of hydrocarbons [5]. The basic unit of each reactor module consists of a set of wires, tubes, plates, monolith or gauze/wire meshes arranged in parallel or series so as satisfy the current-voltage constraints. The smaller dimensions such as spacing and diameter are selected to obtain nearly uniform heating and temperature within the reaction zone. We present recent laboratory results and discuss the material and catalyst design challenges that need to be addressed to advance the decarbonization of the chemical industry through electrified reactors integrated with renewable sources of electricity.

The third part of this talk deals with the direct air capture (DAC) of CO2 and its utilization. Here, a novel monolithic DAC contactor is introduced, markedly enhancing the CO_2 capture rate through its enhanced mass transfer [6]. The contactor employs spiral channels, rather than commonplace straight channels, forming a highly convective secondary flow augmenting CO_2 transport and release to/ from the sorbent layer coated on the monolith channel walls. It is shown that the novel contactor can capture the same CO_2 using about 40% less adsorbent when compared to traditional straight channel contactors. Techno-economic analysis shows the new contactor can reduce the overall DAC cost by about 30%.

References

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Keywords
oxidative coupling of methane; oxidative dehydrogenation of ethane; bi-reforming of methane, direct air capture of CO2