Electricity is in the catalyst:
a reaction engineering approach to gas treatment and valorization

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Introduction

Depending on the heat effect of a chemical reaction, it can be classified as exothermic (releasing heat) or endothermic (requiring heat). Evidently, adequate reactor designs have been developed for each type of reaction, often aiming at transferring the heat either from inside the reactor to a surrounding, cooling medium or from the outside to the reactor internals. Particularly in the latter case, electricity may constitute a viable alternative allowing to mitigate longstanding chemical engineering challenges.

For a strongly endothermic reaction such as methane reforming, whether it is for syngas ($CO + H_2$) formation or hydrogen (H_2) production, relatively narrow reactor tubes are used and suspended in a firebox where gigantic amounts of heat are generated. Transferring the heat from the firebox into the catalyst contained in the reactor tubes is typically the limiting factor in the reactor design (reactor diameter). Changing to electricity for heat supply opens up the opportunity to supply the necessary heat for the endothermic reactions directly inside the reactor, alleviating the need for transferring the heat from the outside to the inside of the reactor. As a result, the reactor diameter is no longer constraint by heat transfer limitations. Various manners can be recurred to, to electrically generate heat in a reactor, i.e., the Joule effect (resistive heating), microwave heating and induction heating.

Materials and Methods

The ElectroThermal Fluidized Bed (ETFB)[1] is a recently developed reactor technology to meet the requirements described in the introduction, see Figure 1. The central part of the reactor comprises a working zone (b) which is characterized by the fully developed fluidized bed situated between 2 electrodes, i.e., a centrally located one and a second one on the internal wall of the reactor. This working zone spans the major part of the reactor height. The fluidized catalyst is made up of the appropriate composition to ensure a meticulous balance between conductivity and resistivity for heat generation.

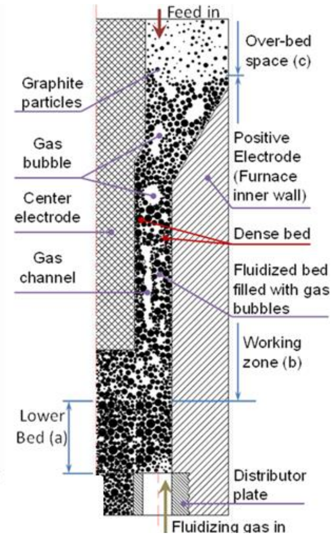

Figure 1: Segmental cross section of a fluidized bed reactor [1]

Results and Discussion

Various applications of the ETFB reactor can be envisaged in the area of methane valorization, such as reforming (syngas formation) or pyrolysis[2] (hydrogen production + solid carbon). An innovative alternative is brought about by the e-CODUCT project[3], which envisages the simultaneous conversion of refinery off-gases such as CO_2 and H_2S according to a three-step process, i.e., (i) COS synthesis by adsorptive reaction of CO_2 and H_2S releasing COS with H_2O remaining on the sorbent, (ii) the pronouncedly endothermic COS decomposition into elemental sulfur and CO and (iii) the upgradation of CO to low carbon fuels and products.

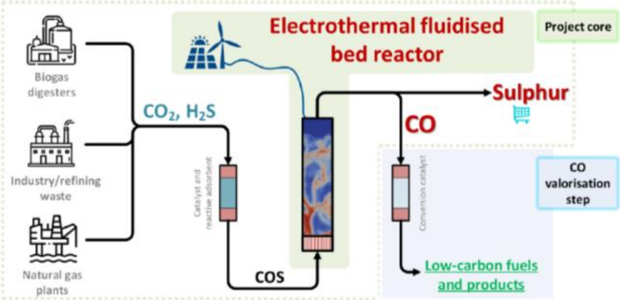

Figure 2. e-CODUCT process for conversion of acid gas into low carbon fuels and products.

Particularly the COS decomposition step[4] is highly endothermic and benefits from being performed in an ETFB reactor configuration. Innovative solutions such as e-CODUCT are crucial in mitigating environmental impact and do so without requiring carbon based energy.

Acknowledgement

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Significance

Electrification is a major driver for rendering the chemical industry more sustainable. Even if it represents one of the highest forms of energy, its ability to be generated from a variety of renewable resources, significantly contributes towards decarbonization.

References

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