Coupling Oxy-fuel Combustion Process to Tri-reforming based Methanol Production Process for CO2 Valorization

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Abstract

Oxy-combustion is a relatively new technology which utilizes nearly pure oxygen rather than air to decrease fuel (coal, natural gas etc) combustion, decrease flue gas volume, decrease NOₓ emissions and generate a CO₂ rich flue gas better suited for CO₂ capture and sequestration application.

Tri-reforming, another relatively new process, developed by Song, 2001 utilizes flue gas and methane to deliver synthesis gas as a product. The process utilizes CO₂, H₂O and O₂ (components of flue gas) in its reaction mechanism while N₂ acts as an inert. So, the flue gas generated by oxy-combustion can directly be utilized in the process without requiring oxygen or water separation.

One of the major drawbacks of the tri-reforming process is presence of nitrogen in the generated synthesis gas (due to high N₂ content in feed flue gas) which (i) reduces the partial pressure of the reacting components in the reactors (ii) increases the reacting volume thus unnecessarily adding to the size of the reactor (iii) adds to compression costs of the process. Since oxy-combustion technology utilizes nearly pure oxygen in place of air for combustion of coal, generated synthesis gas contains 5.25 % nitrogen as opposed to 70.7 % in air-fired process (Yan, 2015). Thus, in this paper, we propose coupling the two processes to mutually mitigate their drawbacks to deliver better results.

Zhang et al., 2013 developed a process coupling the tri-reforming and the methanol production process to deliver methanol from a feed of flue gas and methane, where a water separation step was added in the midst of the two processes by Dwivedi et al., 2016 as a process improvement. In this paper, we employ an additional steam input stream along with methane and flue gas, as an alternate approach to Dwivedi et al., 2016’s process flowsheet to improve process metrics and generate methanol. In our work, we utilized flue
gas generated from both oxy-fuel combustion and air-combustion in our flowsheet, to compare the results and to demonstrate the advantage of coupling oxy-fuel combustion technology with a tri-reforming based process.

Two parameters, viz. gross margin (GM) and CO₂ mitigation factor (CMF), were utilized to evaluate the two processes. Gross margin (GM) measures the profit generating potential of the process while CMF accounts for both direct and indirect CO₂ emissions (unreacted CO and CH₄ emissions) to accurately measure the CO₂ mitigation ability of the process. It should be noted that while oxy-combustion technology generates synthesis gas of superior composition, it requires pure O₂ in the combustion process and thus its cost needs to be included in GM calculations.

The results involving simulations using Aspen Plus V8.4 clearly indicate improvement in both GM and CMF of the process when the tri-reforming based process is coupled with the oxy-fuel combustion process. The GM and CMF values generated from the oxy-fuel combustion coupled tri-reforming based process are 1.66 times and 38.5 % higher than the tri-reforming based process coupled with the air-combustion process respectively.