Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 1 (2009) 683–688
Energy Procedia
www.elsevier.com/locate/procedia

GHGT-9

Pressure Swing Reforming: A novel process to improve cost and efficiency of CO_2 capture in power generation

Frank Hershkowitz[a,]*, Harry W. Deckman[a], Jeffrey W. Frederick[b], John W. Fulton[b], and Richard F. Socha[a]

[a]ExxonMobil Research and Engineering Co., PO Box 998, Annandale, NJ 08801 USA
[b]ExxonMobil Research and Engineering Co., 3225 Gallows Rd., Fairfax, VA 22037 USA

Abstract

We present a novel method of hydrogen production – applicable to gaseous and distillate fuels – that integrates with a gas turbine and has the potential to reduce the cost and energy required for CO_2 capture.

The Pressure Swing Reformer (PSR) process yields syngas at high efficiency and with the compactness of an autothermal reformer. PSR is a cyclic, reverse-flow reactor that alternates combustion steps to heat the catalyst bed with reforming steps that cool the bed. During these steps the center of the catalyst bed remains at temperatures approaching 1200°C, enabling rapid and high conversion. Heat exchange within the packed-bed results in relatively cool products, resulting in high efficiency. The debits of conventional hydrogen manufacture, such as air separation or high-temperature furnaces, are completely eliminated.

As applied to CO_2 capture, PSR's syngas product is shifted and separated to yield hydrogen and a sequesterable CO_2 stream. The hydrogen is used to fuel a gas turbine for power generation, and is also used to fuel the PSR. The power turbine is further integrated by borrowing compressed air from the turbine to use as a combustion source within the PSR. Recovering CO_2 from high pressure syngas can reduce separation cost, just as in IGCC. But unlike IGCC, PSR is a low-cost reactor system that uses air at the conditions provided by the GT compressor and returns air at conditions appropriate for the expander. Integrated as such, the PSR enables lower cost production of power with CO_2 capture.

© 2009 Elsevier Ltd. Open access under CC BY-NC-ND license.

Steam Reforming; Electric Power; CO2 Capture

1. Technical approach

The fundamental element of the PSR is direct contact heat exchange within a bed of solids, which is described in reference to Figure 1. In a packed bed heat exchanger, the heat capacity of a bed of solids is used to change the

* Corresponding author. Tel.: 908-730-2578
E-mail address: Frank.Hershkowitz@ExxonMobil.Com.

doi:10.1016/j.egypro.2009.01.090

temperature of a gas passing through the bed. In the example of Figure 1, the bed is initially at a cool temperature (red line), and the gas is initially at a higher temperature (blue line). Gas is cooled as it passes through the exchanger, transferring heat to the packing material. The shape of the temperature profiles depends on the rate of heat transfer. When the heat transfer rate is relatively fast, the sharp gradient shown in Figure 1 is observed. This gradient moves across the bed as heat transfer continues, until breakthrough occurs and the outlet temperature begins to rise.

An important feature of packed bed heat exchangers is that there is a large difference between the heat capacity of the gases and the solids. This means that, compared to the void volume in the bed, there is a large volume of gas that moves through the bed. For the profiles of Figure 1, the volume of gas that has passed through bed is over 2000 times the bed void volume. In PSR, the bed is designed to provide high heat transfer coefficients, so that the temperature profiles behave as in Figure 1.

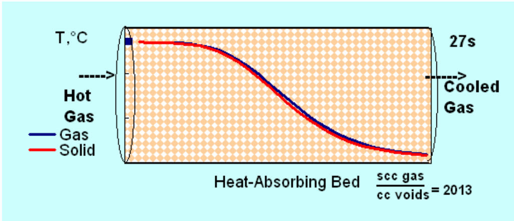

Figure 1: Packed bed heat exchanger

Figure 2 illustrates the use of the packed bed heat exchanger in PSR. Two of these exchangers are placed back to back, with the hot ends together, as shown in Figure 2a. The left bed is roughly twice the size of the right, and it includes reforming catalyst applied to the heat transfer solids. During the regeneration phase of PSR, shown in Figure 2b, air and fuel flow from right to left. Combustion occurs near the interface between the two beds, and the hot flue gas travels through the reforming bed creating a temperature wave and heating the catalyst bed. During the reforming phase, shown in Figure 2c, hydrocarbon and steam flow from left to right. The feed is converted to syngas by the catalyst in the bed, with the sensible and reaction heat being drawn from the bed. Hot syngas leaves the reforming bed and is cooled in the non-catalytic bed on the right, depositing its sensible heat in that bed.

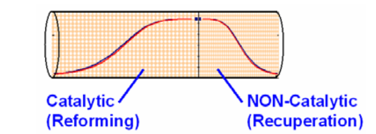

Figure 2a: Two Exchangers

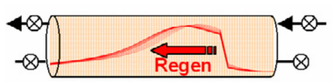

Figure 2b: Regeneration Step

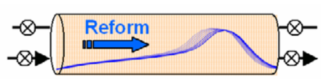

Figure 2c: Reforming Step

This arrangement results in a "heat bubble" within the bed system. During regeneration, air (and regeneration fuel) enter at a relatively cool temperature, are heated by the recuperator, then combust to flue gas near the interface of the two beds. This heat generation expands the bubble, and the flue gas is finally cooled by the heat transfer properties of the reform bed such that flue gas leaves at a relatively cool temperature. Similarly, reform feed enters at a relatively cool temperature, picks up heat and reforms with a relatively high final temperature, and then the product syngas deposits its heat into the recuperator packing before leaving at a relatively low temperature.

2. Computer simulation

The physics and chemistry of Pressure Swing Reforming have been programmed into a numerical simulation of the process. The model includes reforming kinetics (Xu and Froment [1] for methane), heat transfer, pressure drop, axial conduction, and the relevant gas and solid properties. The computational approach is to divide the PSR bed into 30 cells, each representing 1/30th of the bed, to treat each cell as a perfectly mixed reactor, and to march the simulation forward in time. Figure 3 shows predicted temperature profiles at several key times in the simulated PSR cycle.

This simulation is for methane reforming at steam/carbon 1.5 and 8000 hr^{-1} C_1GHSV in a 12 second cycle, with feed temperatures of 250°C and with reforming pressure at 10 atm and regeneration at 1 atm. The bed material is a 1200 cells/inch^2 honeycomb monolith with 7-mil wall thickness. This simulation predicts a very high methane

Download English Version:

https://daneshyari.com/en/article/1514629

Download Persian Version:

https://daneshyari.com/article/1514629

Daneshyari.com