Thermodynamic Performance of IGCC with Oxy-Combustion CO_2 Capture

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ABSTRACT

CO_2 capture from fossil fuel power plants is increasingly proposed for greenhouse gases emission mitigation. However, when applied to conventional coal power stations, by means of post-combustion amine capture or by means of boiler oxy-combustion, severe loss of efficiency and large investment costs can be predicted. To mitigate these drawbacks, CO_2 capture coupled to IGCC can be analyzed. Up to now, the most appealing solution, often quoted by the literature as the one showing the lowest possible cost of avoided CO_2, is based on the syngas decarbonization concept: CO is converted into CO_2 (water-gas shift) and CO_2 is removed from syngas before its combustion by means of physical or chemical solvents. This concept brings to an hydrogen-rich syngas (typically 90% H_2), then burned in a rather conventional gas turbine. The carbon capture cannot exceed 90% and some NO_X emission problems may be encountered due to elevated flame temperature.

An alternative concept, providing better environmental performance, is represented by the oxy-combustion techniques: the CO-rich syngas is basically burned by high purity oxygen in a semi-closed Joule cycle, exhausting a high purity CO_2 stream after water condensation. Any release of combustion gases, including any type of pollutant, is virtually eliminated, approaching 'zero-emission'.

This paper will discuss the relevant thermodynamic aspects of IGCC plants, by analyzing a number of configurations, all based on a dry-feed entrained-flow gasifier with syngas quench (Shell type) and a FB class gas turbine, including:

- A reference case without CO_2 capture, showing an elevated net efficiency of 47.6%.
- A reference case with CO_2 capture, by 'conventional' pre-combustion technique (water-gas shift + physical absorption), showing a much lower efficiency (38.4%) due to many effects related to shift, separation and CO_2 compression.
- An oxy-combustion case, with a conventional gasification process (only modified to use CO_2 rather than N_2 for lock-hoppers pressurization) and the oxy-combustion gas turbine. Particular attention is paid to the design problems related to the novel gas turbine machine. In fact, the different working fluid (mostly CO_2 with some water in the expansion) involves the selection of an higher pressure ratio, larger blade cooling flows, the control of the excess oxygen and so on. However, the re-design of the gas turbine, even if very demanding, is strictly based on known and proven technologies. The CO_2 compression/liquefaction section includes a separation process of the inert gases (O_2, N_2, Ar). This configuration shows better efficiency (40.3%) and better carbon capture, compared to the previous case.
- An advanced oxy-combustion case, intended to predict the performance of a mid-term configuration, including advancements in the gasification section and in the power machines. In particular, an hot-gas-clean-up system for particulate removal and sulfur removal from syngas has been considered, while the gas turbine includes some

foreseeable improvements in the blade cooling to allow for turbine inlet temperature of 1400°C. In this case, efficiency rises to a value close to 45%.

- An evolution of the previous case, which implies the co-sequestration of CO_2 and SO_2, allowing for plant simplification and better efficiency (45.6%) by eliminating the high temperature sulfur removal.

It is concluded that oxy-combustion techniques in IGCC cycles may deserve some attention in the near future, because they have the potential of achieving better thermodynamic and environmental performance, in comparison with more conventional capture concepts. However, some technological challenges are an obstacle to their development, especially as far as the development of a novel gas turbine is concerned, whose details are discussed in the paper.

Keywords: IGCC, CO_2, Capture, Oxyfuel, HGCU.

Proposed Topic: