Technical Assessment of Post-Combustion Carbon Capture using MEA through Process Modifications of (Multi Absorber Feed and Inter-heating Stripper) for Large Scale of combined cycle gas turbine Power Plant

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Abstract

Fossil-fuel is classified as the most dominant energy source. It will be kept as the most essential energy source in the foreseeable future. However, Fossil-fuel combustion in stationary and mobile power supply has a vital role in greenhouse gas (GHG) emissions generation particularly carbon dioxide. In 2019, the atmospheric CO\textsubscript{2} concentration was higher than any time in at least 2 million years (IPCC 2021). Hence, to combat the high concentration of CO\textsubscript{2} increase with the rising fossil-fuel utilisation, a promising technology in the portfolio of solutions should be implemented effectively. One of this potential solution is carbon capture, utilisation, and storage (CCUS). Post-combustion carbon capture (PCC) based on chemical absorption is the identified as most viable technology. However, PCC using the benchmark MEA solvent has two challenges: (a) high energy consumption; (b) high operating and capital costs. To avoid these challenges, we investigated several solutions such as using different solvents and process modifications.

This study aims to study the technical assessment of PCC using MEA solvent through process modifications (multi absorber feed and inter-heating stripper) to evaluate its potential in reducing energy consumption for carbon capture. This aim will be achieved through the following objectives:

- To carry out model development and simulation of PCC using MEA solvent through process modification (multi absorber feed with inter-heating stripper) at pilot scale on Aspen Plus®.
- To carry out model validation of PCC using MEA solvent through process modification (multi absorber feed with inter-heating stripper) at pilot scale on Aspen Plus®.
- To conduct a scale-up of PCC using MEA solvent through process modification (multi absorber feed with inter-heating stripper) to 250 MWe combined cycle gas turbine power plants (CCGT).

In the previous studies through experiments, modelling and simulation, most of them focused on PCC process using MEA solvent (Abu-Zahra et al., 2007; Stec et al., 2015; Oh et al., 2016; Akula et al., 2021). However, the energy consumption reduction was not taken into consideration. Hence, some researchers investigated the process modification such as intercooler absorber where re-boiler duty reduction was by 6.4% (Cousins et al., 2011). on the other hand, split flow arrangement reduced the re-boiler duty by 1.4% (Le Moullec and Kanniche, 2011a). Regarding stripper modification, stripper overhead compression and multi-pressure stripper were deployed, it appeared to be possible to reduce the re-boiler duty by 29.4% and 17% respectively (Le Moullec and Kanniche, 2011b). Some researchers extended the process modification for multiple modifications. For example, lean vapor compression with stripper overhead compression. This modification reduced re-boiler duty by 37.2% (Le Moullec and Kanniche 2011b). Furthermore, rich solvent splitting with multi-pressure stripper was implemented to provide 32.1% re-boiler duty
reduction (Le Moullec and Kanniche, 2011a). Compression modification has higher re-boiler reduction. However, it corresponds to increase the total energy consumption. Based on the previous studies, process modification, multi absorber feed with inter-heating stripper has not been assessed in its superiority in re-boiler duty reduction where there is no profound effect on the total energy consumption.

In this study, model development and validation of solvent-based PCC through process modification; multi absorber feed with inter-heating stripper is implemented and validated at pilot scale in Aspen Plus® against experimental data from Laziska power plant in Poland (Krótki et al., 2020). The results confirmed that the model predictions (e.g. CO₂ capture level (%), CO₂ lean loading (molCO₂/molMEA), CO₂ rich loading (molCO₂/molMEA), specific re-boiler duty (MJ/kgCO₂), and temperature profile for the stripper are in agreement with the experimental data. A regeneration energy of 3.78 MJ/kgCO₂ was obtained for the PCC using multi absorber feed and inter-heating stripper, while it was 4.25 MJ/kgCO₂ for process in case of multi absorber feed. Regarding specific re-boiler duty, the results shows that multi absorber feed with inter-heating reduces the re-boiler duty by 11% compared to the conventional configuration (multi absorber feed). In case of inter-heating stripper addition, the total solvent heat exchange increases and a part of the heat from re-boiler is exchanged inside of stripper rather than external heat exchangers, which reduces the heat losses. Scale up will be deployed to 250 MWe combined cycle gas turbine power plant to accommodate the flue gas extracting from the CCGT power plant. The expected specific re-boiler duty for large scale will be below lower than specific re-boiler duty of conventional configuration 4.97GJ/tonCO₂.

**Keywords:** Post-combustion CO₂ capture; Chemical absorption; Scale-up; Combined cycle gas turbine power plant; Multi absorber feed; Inter-heating stripper

**References**


