FEASIBILITY OF FLUIDIZED BED REACTOR SYSTEMS FOR PRESSURIZED CHEMICAL LOOPING COMBUSTION OF NATURAL GAS

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Chemical looping combustion (CLC) of natural gas at atmospheric pressure has been successfully demonstrated at technical laboratory scale (120 kWth) since 2009 (1,2). Scale-up studies to 10 MWth have been presented (3,4), but no pilot or demonstration projects have been executed so far. Instead, researchers have recently concentrated their activities on CLC of solid fuels (5). One reason for this is the deployment challenge for natural gas CLC power plants. State-of-the-art gas-turbine combined cycle (GT-CC) plants reach high electric efficiencies up to 60% and are superior to steam cycle concepts even if post combustion CO2 capture is applied. On the other hand, all the early studies on CLC focused on efficiency increase for GT-CC plants through application of CLC (6,7). The present contribution therefore seeks to address this mismatch and to assess the practical potential of natural gas CLC for power production. A principal baseline is the application of atmospheric pressure CLC and steam cycle power generation reaching electric efficiencies up to 45% dependent on steam parameters and plant size. In order to reach higher electric efficiencies, pressurized CLC and gas turbine cycles would need to be implemented. Fluidized bed systems have been proposed for CLC (8) and preferred so far for they combine good heat management and continuous operation. If CLC is used in combination with gas turbines, at increased pressure, the operation of fluidized bed systems is challenging. Process configurations have been compared based on mass- and energy balances and basic design calculations have been carried out based on fluidization engineering methods. It turns out that high gas turbine efficiencies can only be reached if turbine inlet conditions are sufficiently high and relative pressure losses are within reasonable limits. Based on the results of the present work, the efficiencies of CLC based power generation cycles remainsignificantly lower than standard GT-CC efficiencies without CO2 capture. An optimal range of operating conditions can be identified for operation of a pressurized CLC plant with increased efficiency and design considerations for a dual circulating fluidized bed reactor system are reported. Such systems are characterized by solids transport ducts and loop seals of increased dimensions relative to atmospheric pressure systems. Accordingly, also the fluidization gas (steam) demand for loop seals is relatively increased for pressurized systems. The outcome of this work may serve as a general basis for techno-economic evaluation of pressurized CLC systems for power generation.

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FIGURES AND TABLES

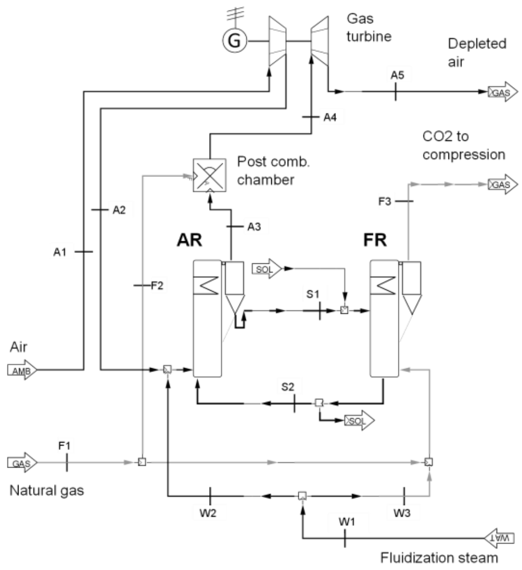

Figure 1: Arrangement of a pressurized dual circulating fluidized bed reactor system for chemical looping combustion of natural gas.

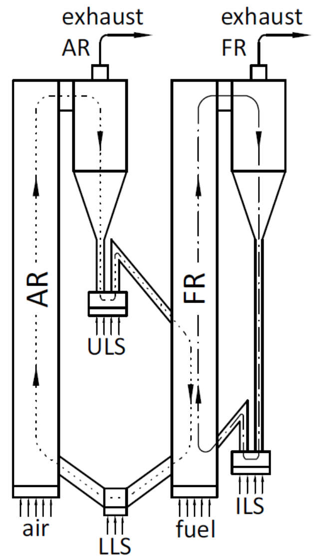

Figure 2: Dual circulating fluidized bed (DCFB) reactor system.

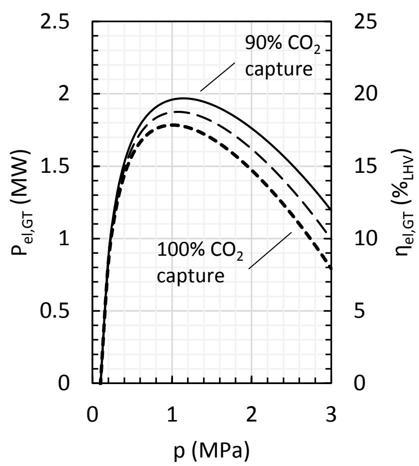

Figure 3: Gas turbine power for different air reactor pressure levels and capture efficiency targets.

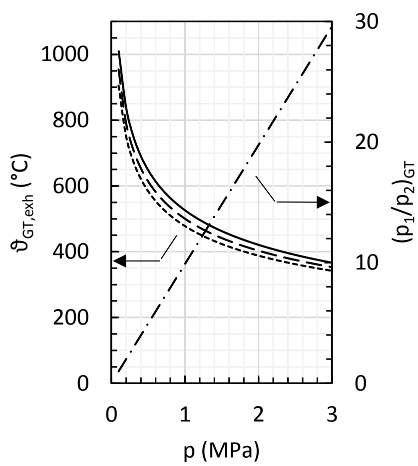

Figure 4: Gas turbine outlet temperature and pressure ratio for different air reactor pressure levels and capture efficiency targets.