Oxygen Carriers in Fluidized Bed Combustion of Biomass for Higher Efficiency, Reduced Emissions and (or) Negative CO_2

Acronym: OxyCar-FBC

Coordinator:
Chalmers University of Technology (S)

Partners:
- **Technical University of Vienna (A)**
- **Bertsch Energy (A)**
- **Göteborg Energi (S)**

Associated partners:
- **SSAB Merox (S)**
- **Sibelco Nordic (S)**

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Contact: [Chalmers University of Technology]

Introduction

In the this project two new processes were investigated for efficient and climate-friendly generation of energy from biomass, based on the fluidised bed method. A robust, flexible and low-emission combustion technology, frequently used today for the combustion and gasification of biomass.

Quartz sand generally serves as the fluidised bed material. The key approach of OxyCar-FBC is to replace the typical bed material partially or entirely with metal oxides that can be used for transfer of oxygen in, or between, fluidized beds. They are used in the two processes:

1. “Oxygen Carrier Aided Combustion” or OCAC and
2. “Chemical-Looping Combustion” or CLC.

In OCAC the oxygen carrier firstly acts as an oxygen buffer that can accommodate for variations in fuel flow or quality and secondly transfers oxygen from fuel rich to fuel lean zones of the combustion chamber. CLC is a form of unmixed combustion; thus the combustion air is not allowed to mix with the fuel. Instead the air and the fuel are added to two different, but interconnected fluidized-beds, the air reactor and the fuel reactor. The oxygen carrier does the job of transferring the oxygen from the air reactor to the fuel reactor.

In CLC the combustion products, CO_2 and H_2O, leave the process in a separate stream. Ideally a pure stream of CO_2 can be achieved after H_2O condensation, but in reality full gas conversion is not reached and some oxygen needs to be added to the gas stream leaving the fuel reactor, which is called oxy-polishing. Thus, the process allows for efficient capture of CO_2 from combustion.

CLC could have additional advantages. Thus, difficulties with fouling and corrosion of boiler tubes may potentially be reduced or eliminated. Assuming the impurities leading to corrosion -such as K, Na and Cl - are exclusively or predominantly released in the fuel reactor which has no cooling, most of the heat extraction will take place in absence of these. The smaller heat extraction from gas leaving the fuel reactor can be adapted for alkali, e.g. with lower surface temperatures. Similarly, NOx emissions will also be concentrated in the small CO_2 flow, allowing for significantly reduced costs of NOx removal.

Results

In the project OxyCar-FBC, several oxygen carrier materials have been investigated in actual operation in different units, both for chemical-looping combustion with oxygen uncoupling (CLOU) and OCAC. The units include a small 300 W CLC reactor system for gaseous fuels used for screening, three CLC units for solid fuels with a thermal power of 10 kW, 80 kW and 100 kW, a 10 MW circulating fluidized-bed boiler and a 100 MW bubbling fluidized bed boiler. Low-cost materials studied involve ilmenite ore, several manganese ores and LD-slag, a waste material from steel industry. With one exception operation has been stable and worked well.

Results clearly indicate that manganese ores have potential for reaching better conversion than the state-of-the-art oxygen carrier ilmenite, and good performance was also seen for the LD-slag. The LD-slag was also used for OCAC in a two-week long campaign in the 10 MW CFB, verifying that the material worked well as bed material with no problems related to material handling, agglomeration or sintering at any occasion. The slag was not deactivated by biomass ash and largely retained its reactivity.

In summary, the project has given important experiences and a significantly increased understanding of CLC and OCAC operation with biofuels, using novel oxygen carriers. The work clearly demonstrates the viability of the CLC process for negative emissions.

The project has also investigated novel fuel reactor designs that will improve conversion by improving the contact between gas and oxygen carriers. Furthermore, a techno-economic study has been made including a design of a 100 MW CLC boiler. The study confirms the potentially very low costs of CO_2 capture. A comparison to a reference CFB boiler, indicates an added cost of 5 €/ton CO_2 for the CLC boiler. This does not, however, include the costs for making the CO_2 ready for storage, which involves e.g. oxy-polishing and compression. These would likely add another 15 €/ton CO_2 in cost, but CLC is still expected to cost less than half of competing technologies.

The long failure to adequately address greenhouse gas emissions, has led to a situation where the carbon budget for important climate targets is soon exhausted. Prevalent scenarios to address climate targets include very large negative emissions using BECCS, i.e. bioenergy carbon capture and storage. BECCS using conventional CO_2 capture technologies is associated with large costs and energy penalties for gas separation. Because CLC can avoid gas separation, it has potential to dramatically reduce the costs of BECCS, which could be very important for the climate.

Acknowledgment

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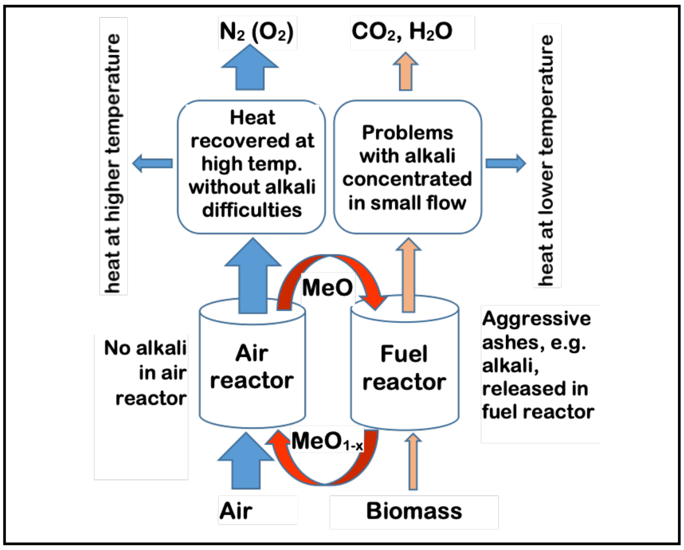

Fig. 1. CLC principle and potential advantages with respect to alkali

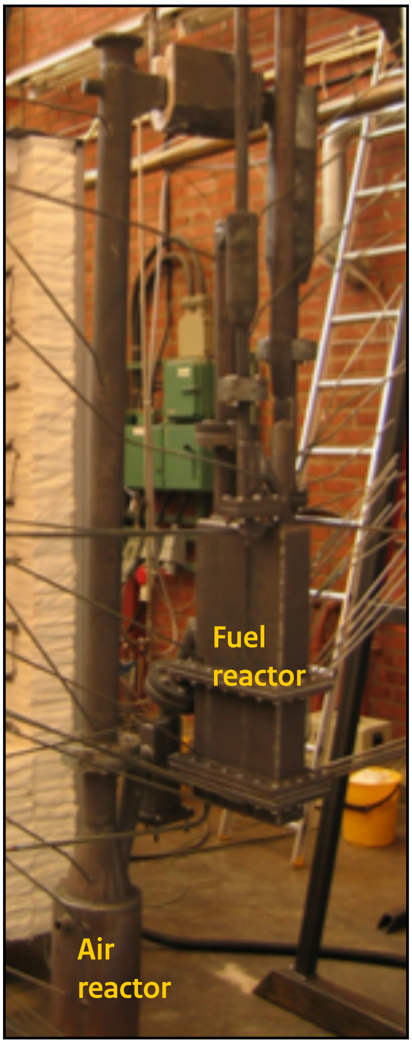

Fig. 2. Chalmers 10 kW solid-fuel chemical-looping combustor system

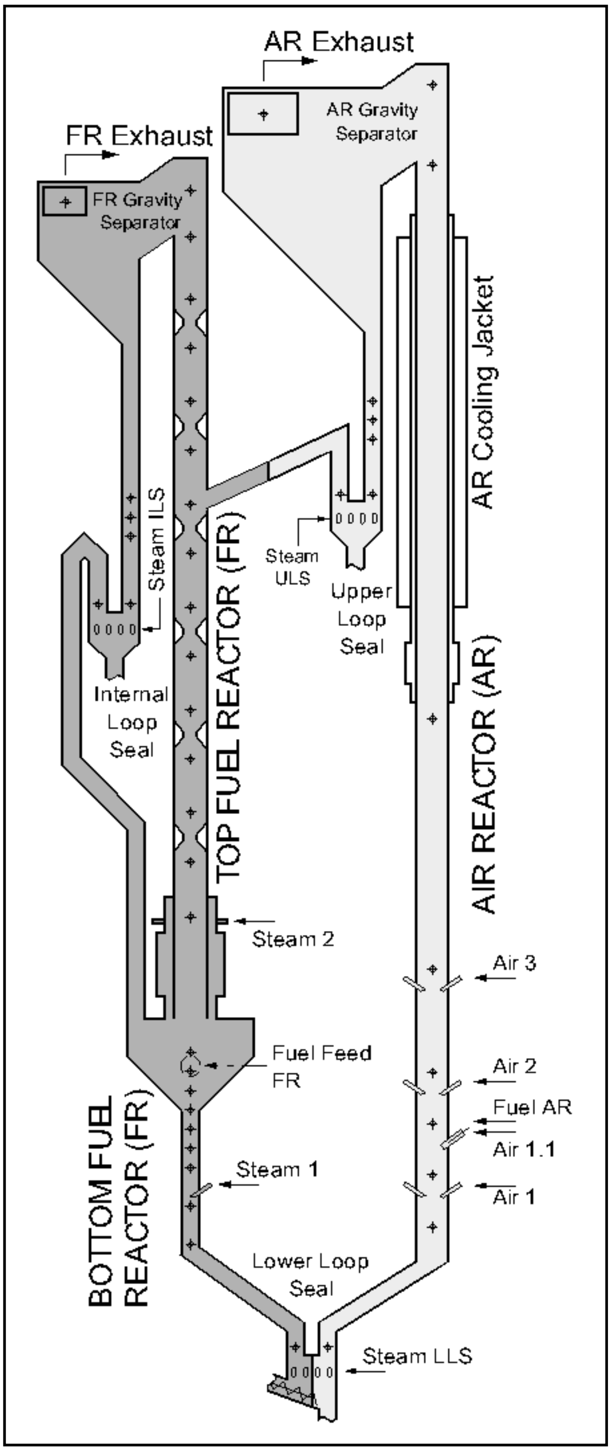

Figure 3: 80 kWth CLC pilot unit at TU Wien.

Figure 4: Picture of 80 kWth pilot unit at TU Wien.

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