CHALMERS

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Chemical-Looping Combustion with Liquid Fuels

Contact information

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Summary

A project devoted to establishing chemical-looping combustion with liquid fuels currently being conducted by Chalmers University of Technology with support from Saudi Aramco is presented. The ultimate goal of the project is to develop technology capable of utilizing and processing heavy residual oils with inherent CO_2 capture.

Heavy oil residues are intermediate products from oil refineries. Some of those residues can be blended with lighter oil fractions to produce fuel oils, while others are waste products. Heavy oil residues are highly viscous at ambient temperature and contain high amounts of impurities such as sulfur, up to 6 wt-%, and metals, up to 1000 ppm. Using such fuel in a stationary combustion process with separation of CO_2, namely chemical-looping combustion, might be an interesting option. The use of kerosene and fuel oil are intermediate steps in the upscaling of the process.

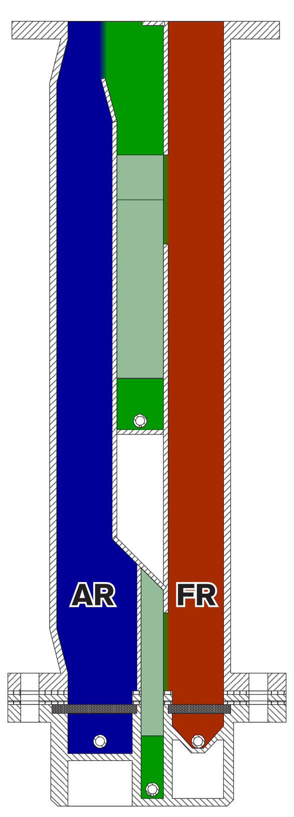
Aims of the project

- Develop chemical-looping combustion with liquid fuels, namely heavy oil residues.
- Find a suitable oxygen carrier that is resistant to sulfur poisoning.
- Over the course of the project, the process is scaled up to larger chemical-looping reactors and heavier liquid fuels.
- Evaluate the feasibility of an industrial-scale chemical-looping combustion unit with CO_2 sequestration that uses heavy oil residues as fuel.

Conclusions

- In phases I and II, experiments with kerosene, sulfurous and sulfur-free, were conducted for a total of 234 h with addition of fuel.
- Eight different oxygen carrier materials were tested.
- Two of the eight materials were found to be suitable for further investigation. They were tested with sulfurous kerosene and will be used in a 10 kW_{th} unit in phase III.

Project structure



CLC reactor

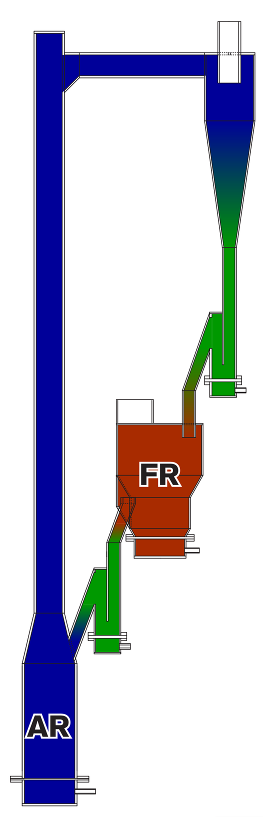
Design capacity	300 W_{th}
Reactor height	30 cm
Fuel reactor area	25x25 cm

Fuels

Two types of kerosene, one sulfur-free and one with sulfur.

Aims

1. Design, build and test an injection system for fuel feed.
2. Screen different oxygen carrier materials and select suitable ones for scale-up.



CLC reactor

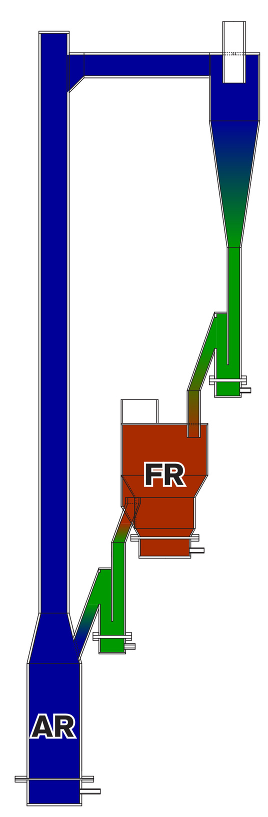
Design capacity	10 kW_{th}
Riser height	2.23 m
Fuel reactor area	ø150-260 cm

Fuel

Fuel oil similar to diesel or gasoline.

Aims

1. Design, build and test an injection system for direct injection of liquid fuel.
2. Gain experience during 100+ experimental hours.



CLC reactor

Design capacity	10 kW_{th}
Riser height	2.23 m
Fuel reactor area	ø150-260 cm

Fuel

Heavy oil residues
- high viscosity (solid at 20°C)
- 5.4 wt% sulfur
- metal content: V, Na, Ni, Cl, ...

Aim

Utilize heavy oil residues as fuel in chemical-looping combustion.

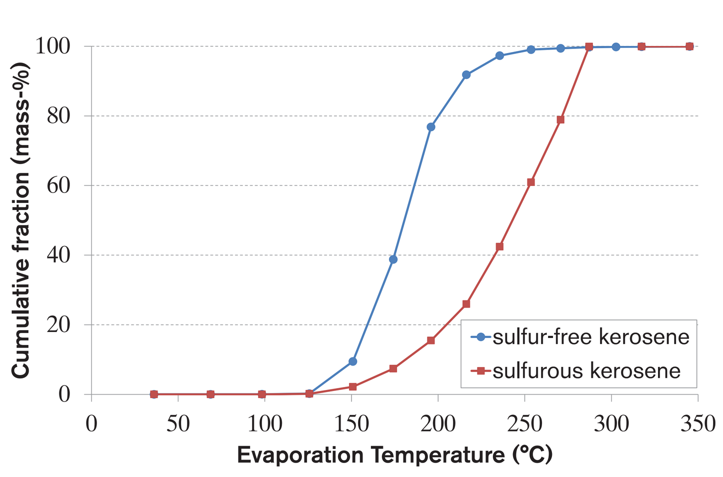
Techno-economic study

The costs and feasibility of an industrial scale unit that uses heavy oil residues as fuel will be assessed. The heat produced can be used for other industrial processes or for power generation.

Sequestration of CO_2 is an inherent part of a chemical-looping combustion process. This means that the feasibility of such a plant will largely depend on the price of CO_2 emissions.

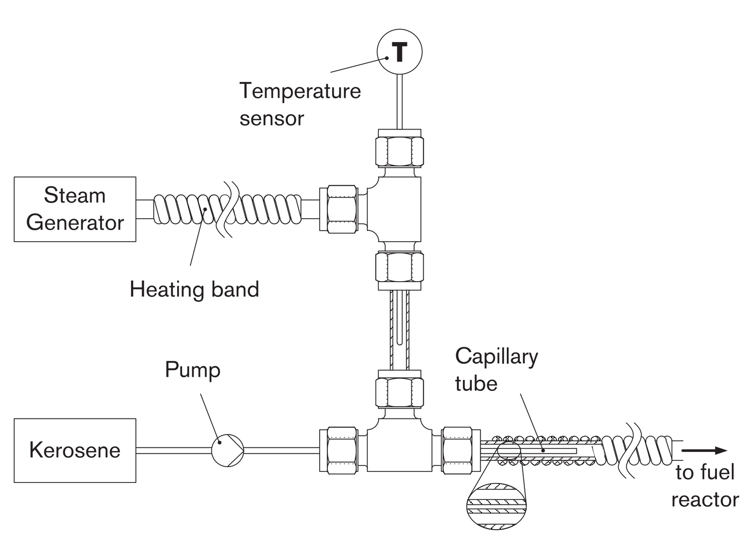
Phases I and II (completed) → Phase III-1 (on-going) - - → Phase III-2 - - → Phase IV - -

Experimental setup in phases I and II

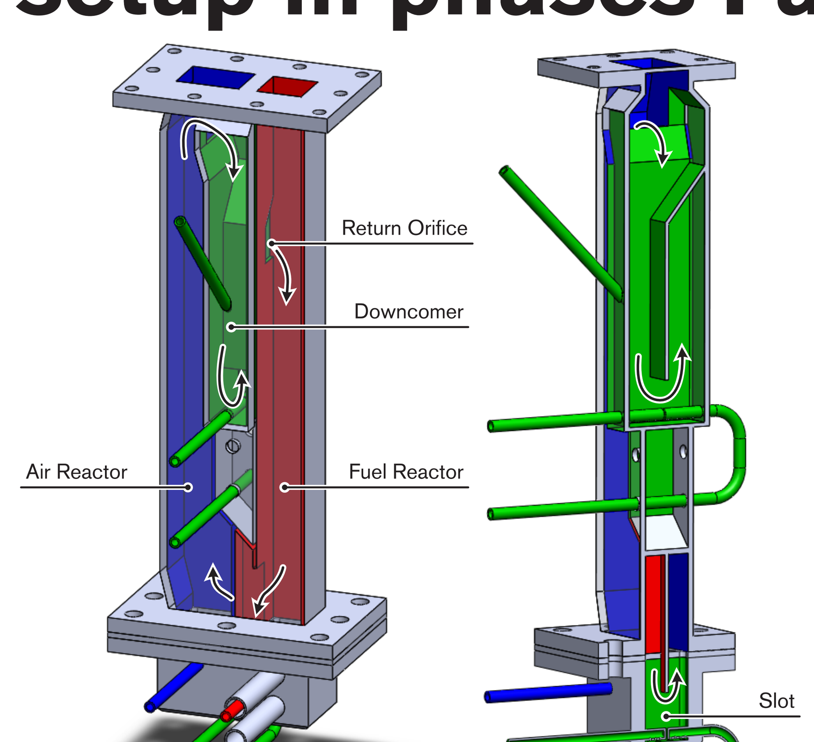


Fuel property	Sulfur-free kerosene	Sulfurous kerosene
C content (mass-%)	86.2	85.9
H content (mass-%)	13.5	13.5
S content (mass-%)	0	0.57
Lower heating value (MJ/kg)	43.34	42.66
(MJ/dm³)	34.33	36.69
Hydrogen-to-carbon ratio (mol/mol)	1.87	1.87

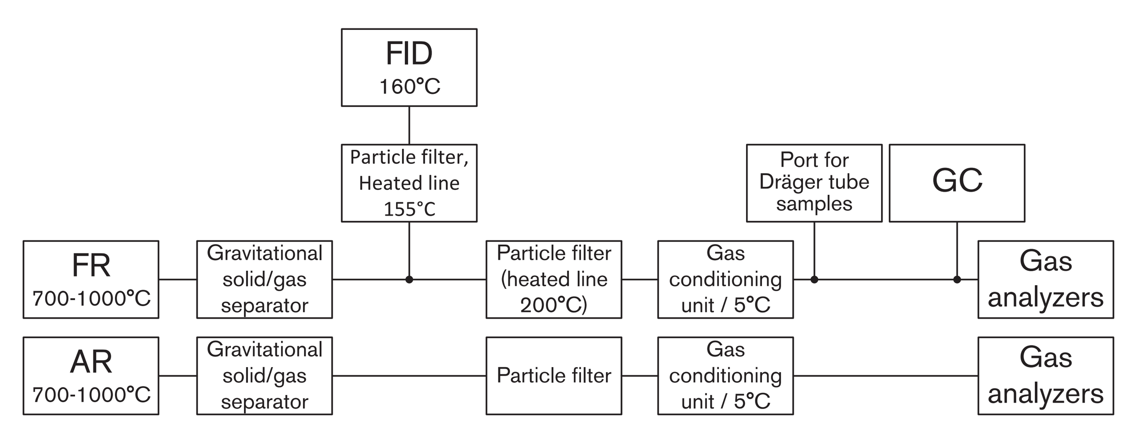
Fuel analysis



Injection system



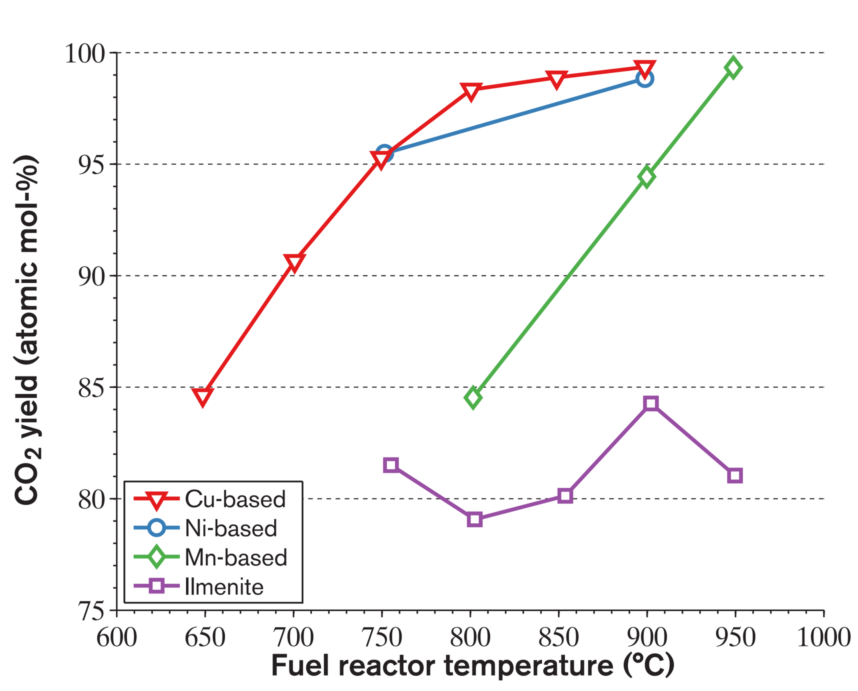
300W chemical-looping reactor



On-line gas measurement system

Results from phases I and II

	Fuel conversion	Attrition resistance	Agglomeration tendency	Sulphur resistance	Costs
Cu-based	++	+	–	++	–
Ni-based	++	–	++	not tested	– –
Mn-based	+	– –	+	not tested	–
Ilmenite	–	++	+/–	++	++



Key results summarized (table above)

+ *positive characteristic*
– *negative characteristic*

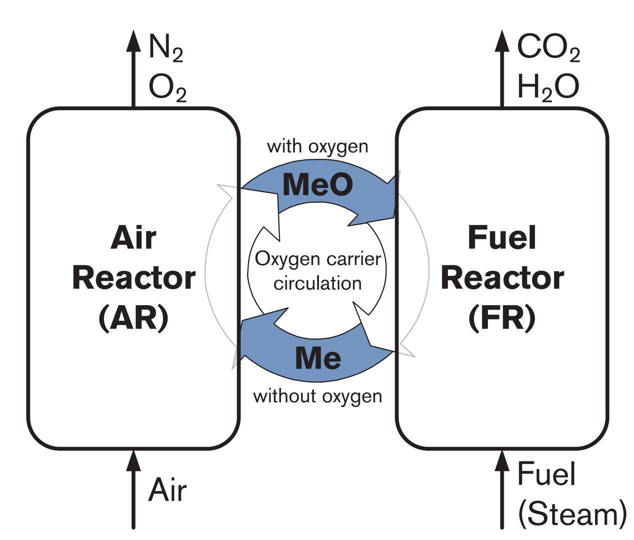
Cu-based oxygen carrier and ilmenite were selected for further testing in phase III.

Fuel conversion (figure left)

CO_2 yield: molar amount of fuel carbon converted to CO_2

- 300 – 400 g oxygen carrier particles
- 100 – 200 µm initial particle size
- 144 W_{th} (0.25 ml_{liq}/min) fuel flow
- 7.7 H/C molar ratio (through steam addition)

Chemical-looping combustion



- Two interconnected fluidized-bed reactors
- No exchange of gas between reactors, i.e. air and fuel are not mixed
- Oxygen is transported to the fuel by a solid oxygen carrier, which is cyclically oxidized and reduced
- Net heat of reaction is the same as for regular air combustion, i.e. there is no energy penalty for separation of CO_2

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