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The use of ilmenite as oxygen carrier with kerosene in a 300W CLC laboratory reactor with continuous circulation

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Summary

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 is an intermediate step in the upscaling of the process.

An ilmenite oxygen carrier was tested in a laboratory scale chemical-looping reactor with a design thermal capacity of 300 W. Ilmenite is a mineral iron-titanium oxide, which has been used extensively as an oxygen carrier in CLC. Two different kinds of fuels were used, a sulfur-free kerosene and one that contained 0.57 mass-% sulfur. Both fuels were continuously evaporated and directly fed into the chemical-looping reactor. Experiments were conducted for 50 h with the sulfur-free kerosene and for 30 h with the sulfurous kerosene. CO_2 yields above 99% were achieved with both types of fuel. It seems that a significant and lasting improvement in the oxygen carrier's reactivity was achieved by using sulfurous kerosene. No evidence of sulfur was found on the particles' surface.

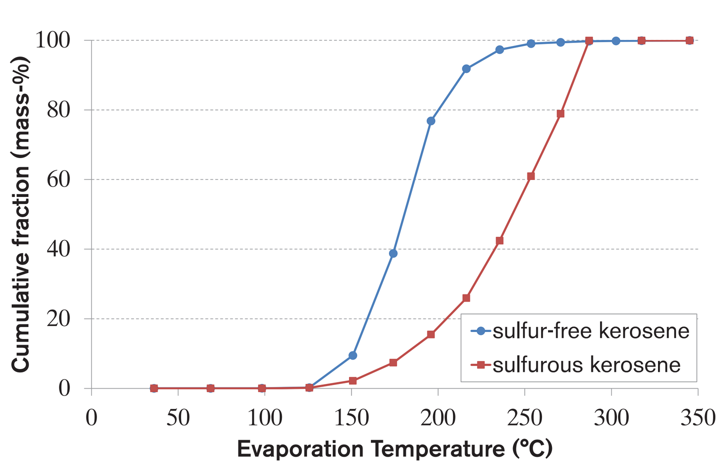
Aims of the project

- 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.

Conclusions

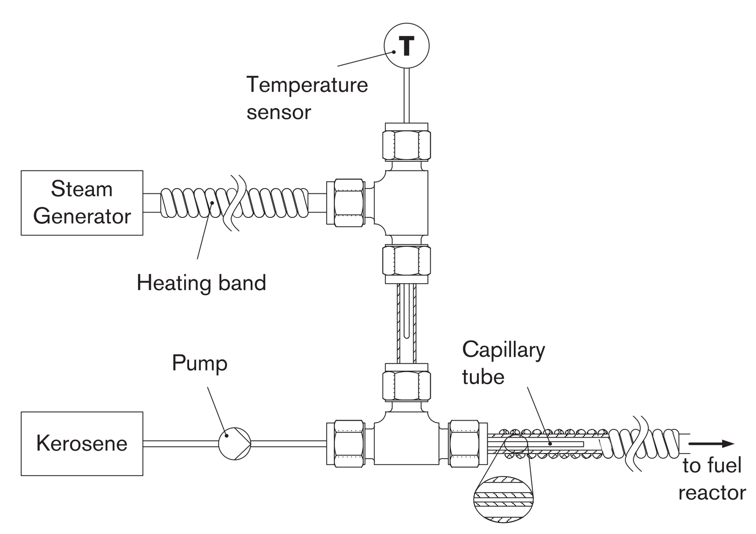
- With both types of kerosene, CO_2 yields above 99% were reached at 950°C and fuel flows equivalent to 144 W_{th}.
- The presence of sulfur seems to have a positive effect on the reactivity of oxygen carrier. Reactivity increased when sulfurous kerosene was used and stayed on a higher level even when sulfur-free kerosene was used thereafter.
- No evidence was found for sulfur poisoning or deactivation of the oxygen carrier.

Experimental

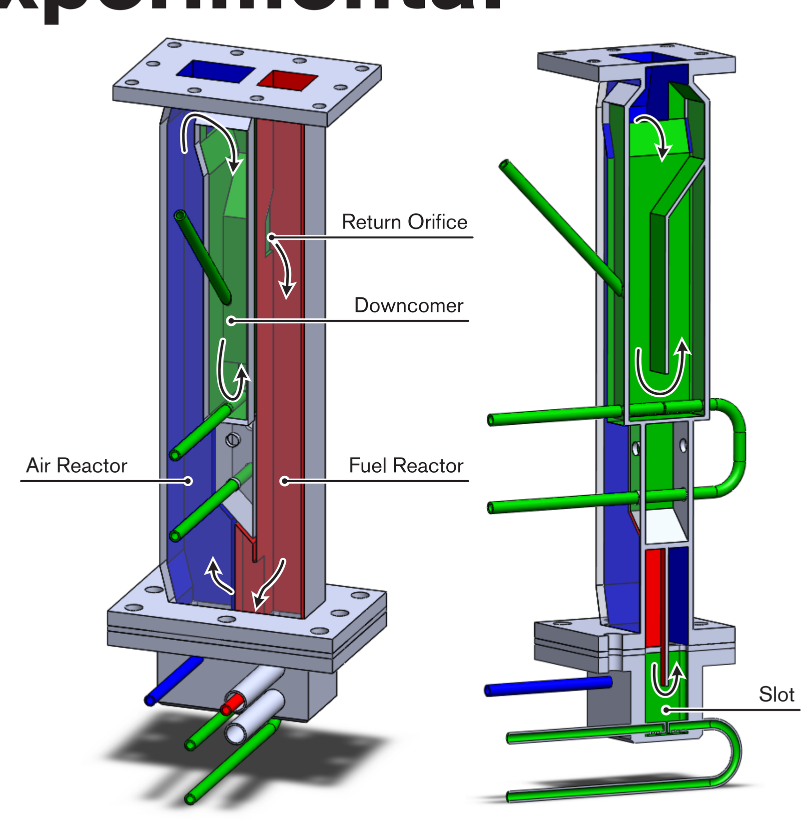


Fuel property	Sulfur-free kerosene	Sulfurous kerosene
C content (mass-%)	86.2	85.9
H content (mass-%)	13.5	13.5
S content (mass-%)	0	0.57
Lower heating value (MJ/kg)	43.34	42.66
(MJ/dm³)	34.33	36.69
Hydrogen-to-carbon ratio (mol/mol)	1.87	1.87

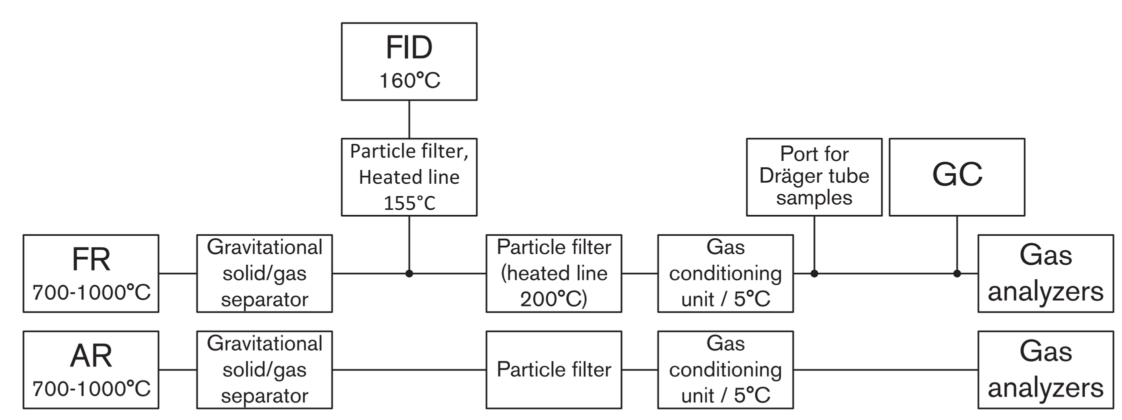
Fuel analysis



Injection system

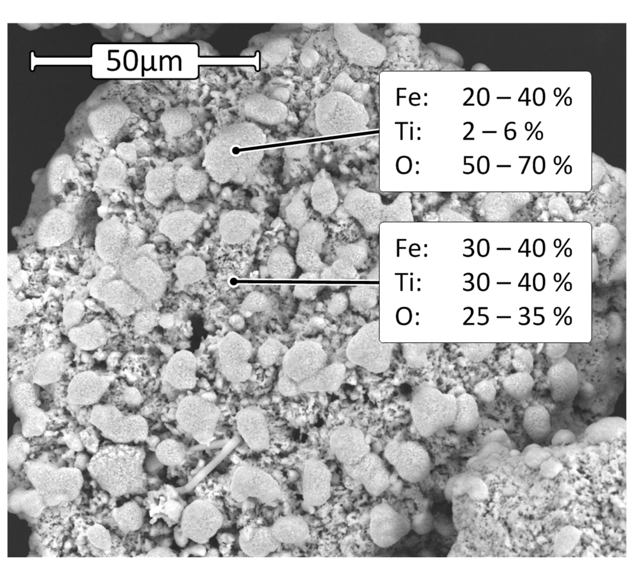


300W chemical-looping reactor

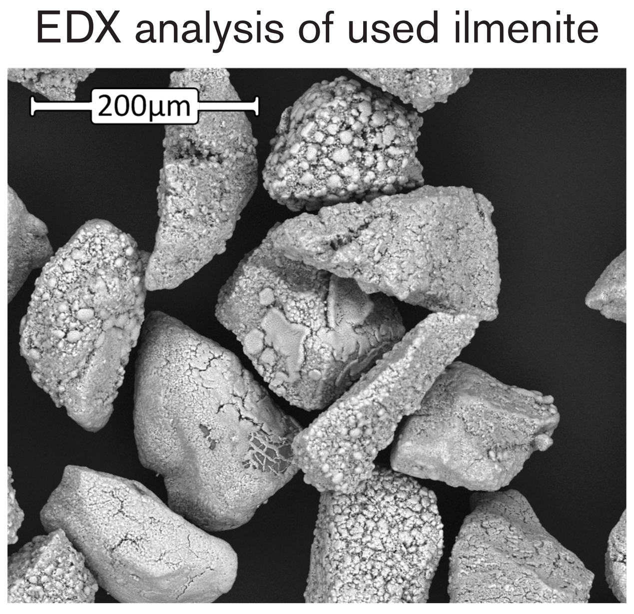


On-line gas measurement system

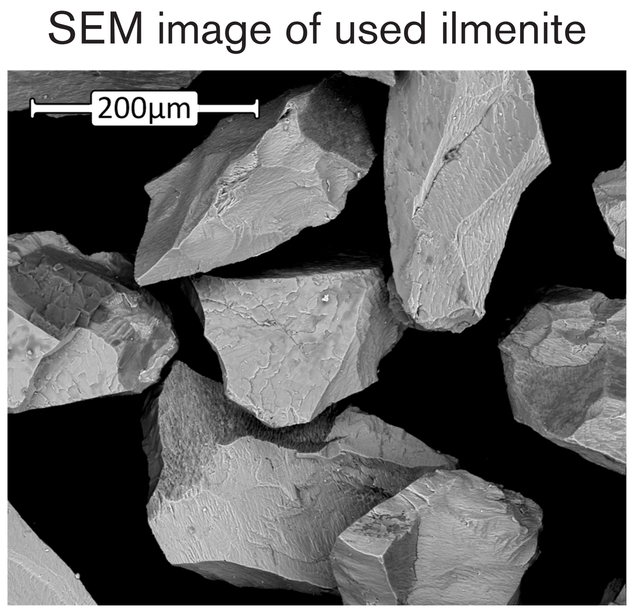
Results



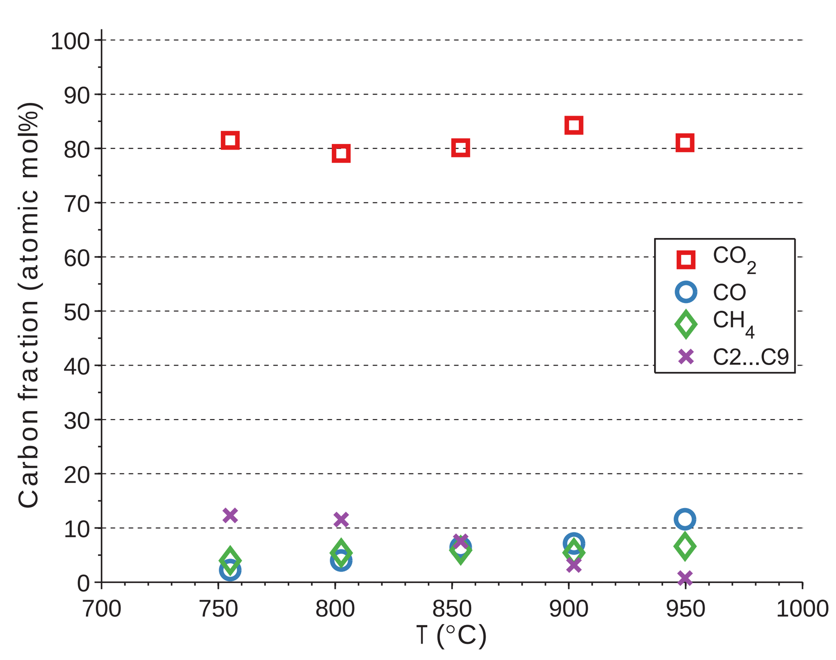
EDX analysis of used ilmenite



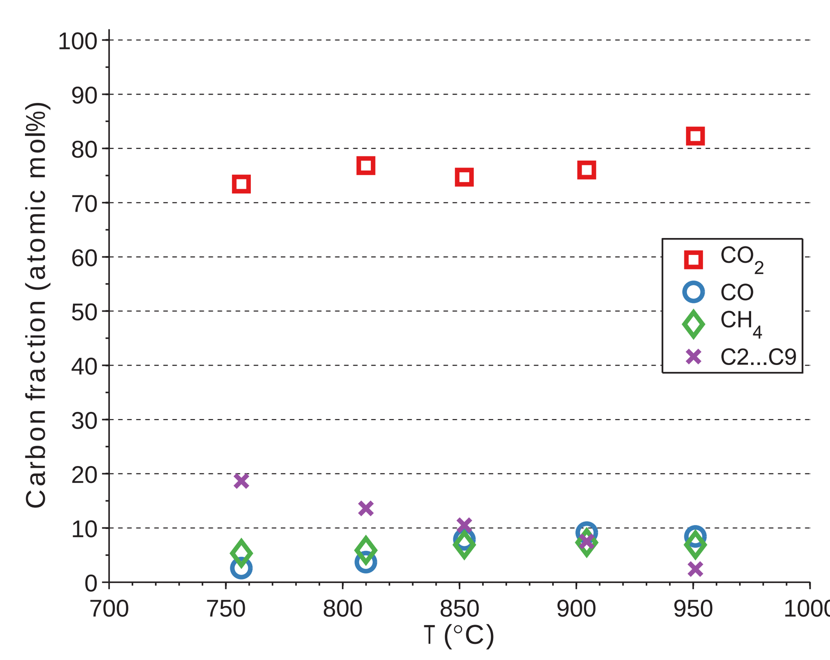
SEM image of used ilmenite



SEM image of fresh ilmenite

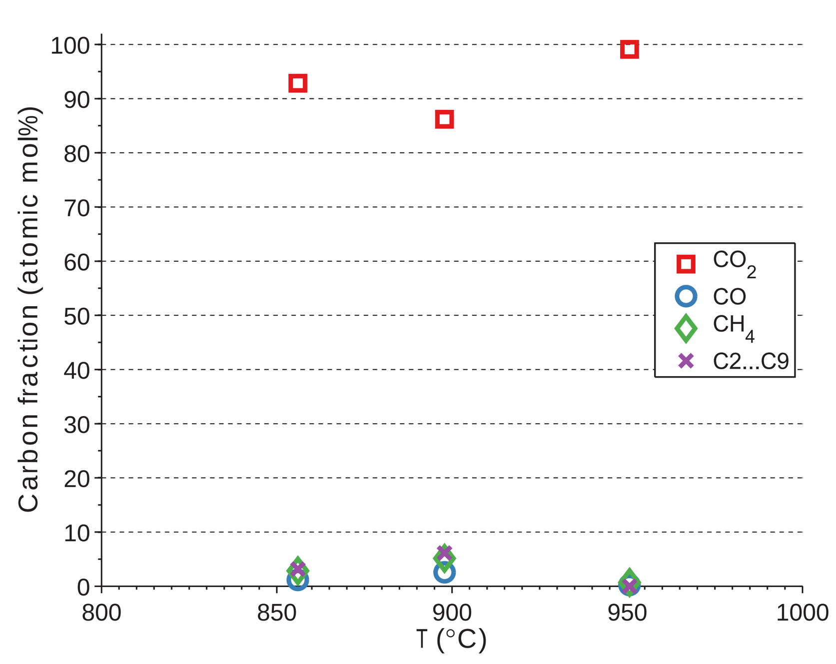


143 W_{th} (0.25 ml_{liq}/min)

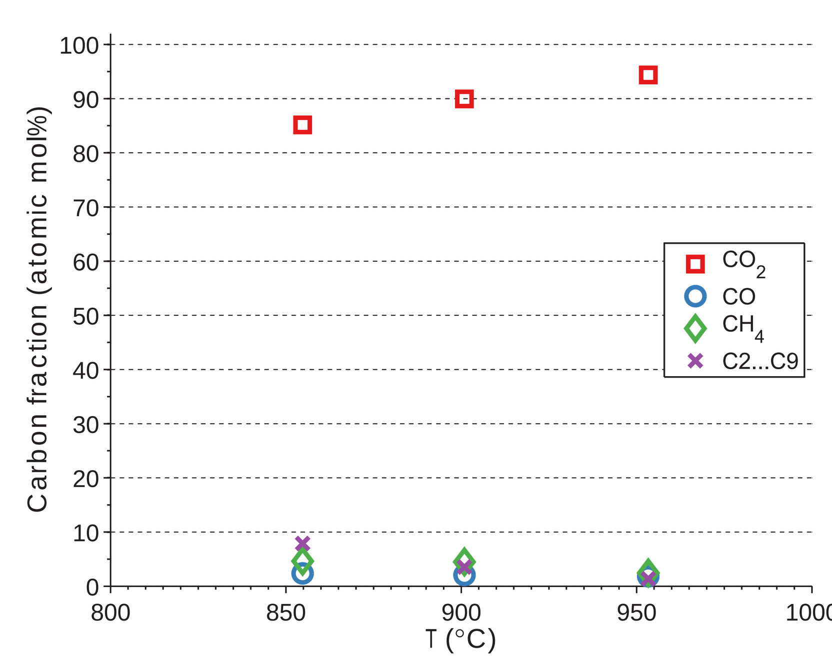


286 W_{th} (0.50 ml_{liq}/min)

Carbon fractions for different flows of sulfur-free kerosene

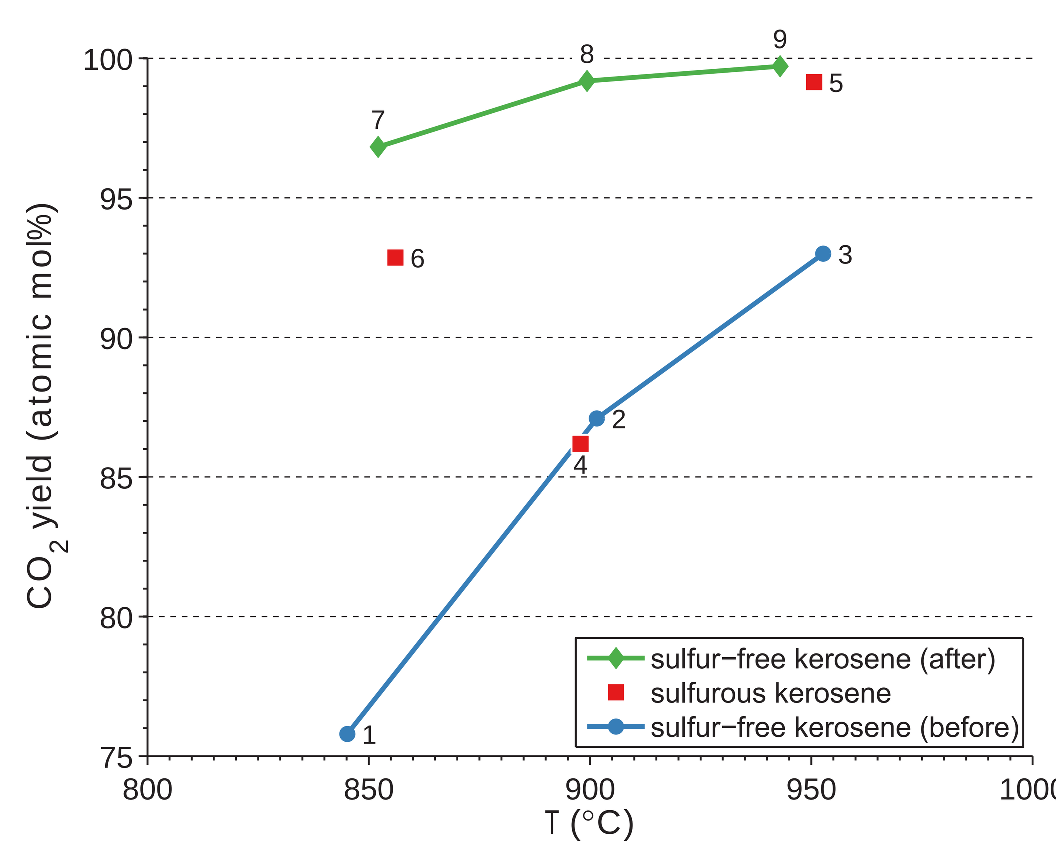


144 W_{th} (0.236 ml_{liq}/min)



300 W_{th} (0.492 ml_{liq}/min)

Carbon fractions for different flows of sulfurous kerosene



Comparison of experiments with sulfur-free and sulfurous kerosene. A constant fuel flow equivalent of 144 W_{th} was used. The numbering of the points corresponds to the order in which the experiments were performed.

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