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CO_2 Capture from Combustion of Biomass Volatiles with a Chemical-Looping Combustion Process

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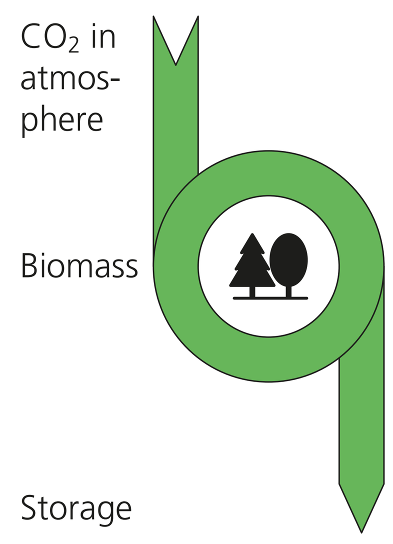
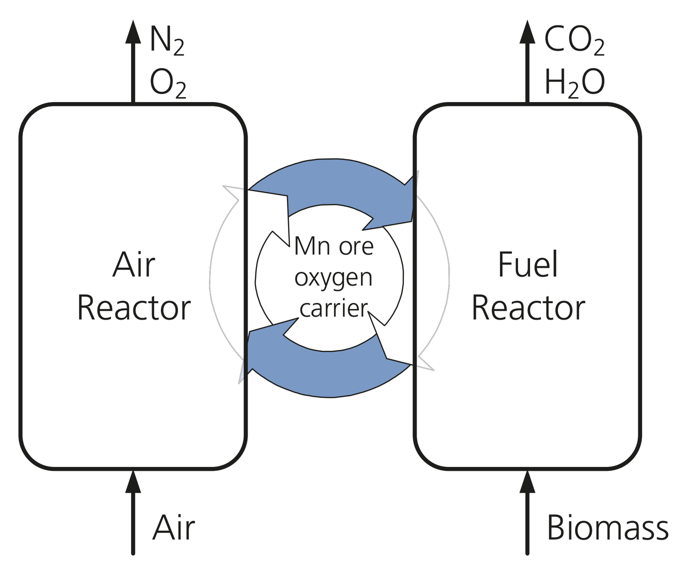
Summary



Capture and storage of CO_2 from combustion of biomass, i.e., bio-energy carbon capture and storage (BECCS), makes it possible to obtain so-called negative emissions – the atmosphere is cleansed from carbon dioxide. In this study, five manganese ores are investigated as oxygen carriers in chemical-looping combustion of biomass fuels. A laboratory-scale chemical-looping combustion (CLC) system was used, which has a nominal fuel input of 300 W_{th}. The aims were to investigate the reactivity of these oxygen carriers towards biomass fuels as well as their mechanical stability. A synthetic "biomass volatiles" gas – representing the gas generated during devolatilization of a wood-based fuel – was used as fuel in this study, and it was studied how the different gas components react with the oxygen-carrier particles. Additional experiments were conducted with methane and a syngas. Parameter studies concerning temperature and specific fuel-reactor bed mass (in kg/MW_{th}) were carried out. With the synthetic biomass volatiles, conversion of fuel carbon to CO_2 as high as 97.6% was achieved. For a majority of the investigated ores, essentially all C2 and C3 hydrocarbons were converted, as well as a very high fraction of the CO. Reactivity towards CH_4 on the other hand was generally lower, but improved at higher temperatures.

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.



Conclusions

- It is possible to remove CO_2 efficiently from the atmosphere through a chemical-looping combustion process with biomass as fuel. The use of manganese ores has the potential to keep the costs of the CLC process low.
- The properties of the five manganese ores investigated differed significantly and, hence, it is likely that other ores exist that are even better suited.
- The attrition resistance of two of the materials was higher than for the other Mn ores tested. Their attrition was similar to that of ilmenite (Fe-Ti-based mineral).
- All of the manganese ores also showed oxygen uncoupling, which could be an advantage in large boilers, with inadequate mixing.

Result

	Mechnical attrition	Redox attrition	Biomass reactivity	Methane reactivity	Syngas reactivity
Elwaleed C	– –	+	+	–	+
Tshipi	○	– –	+	n/a	++
Gui Zhou	+	++	+	○	++
Braunite	+	+	○	–	++
Morro da Mina	+	–	–	n/a	n/a

\+ favorable property ○ average property – unfavorable property

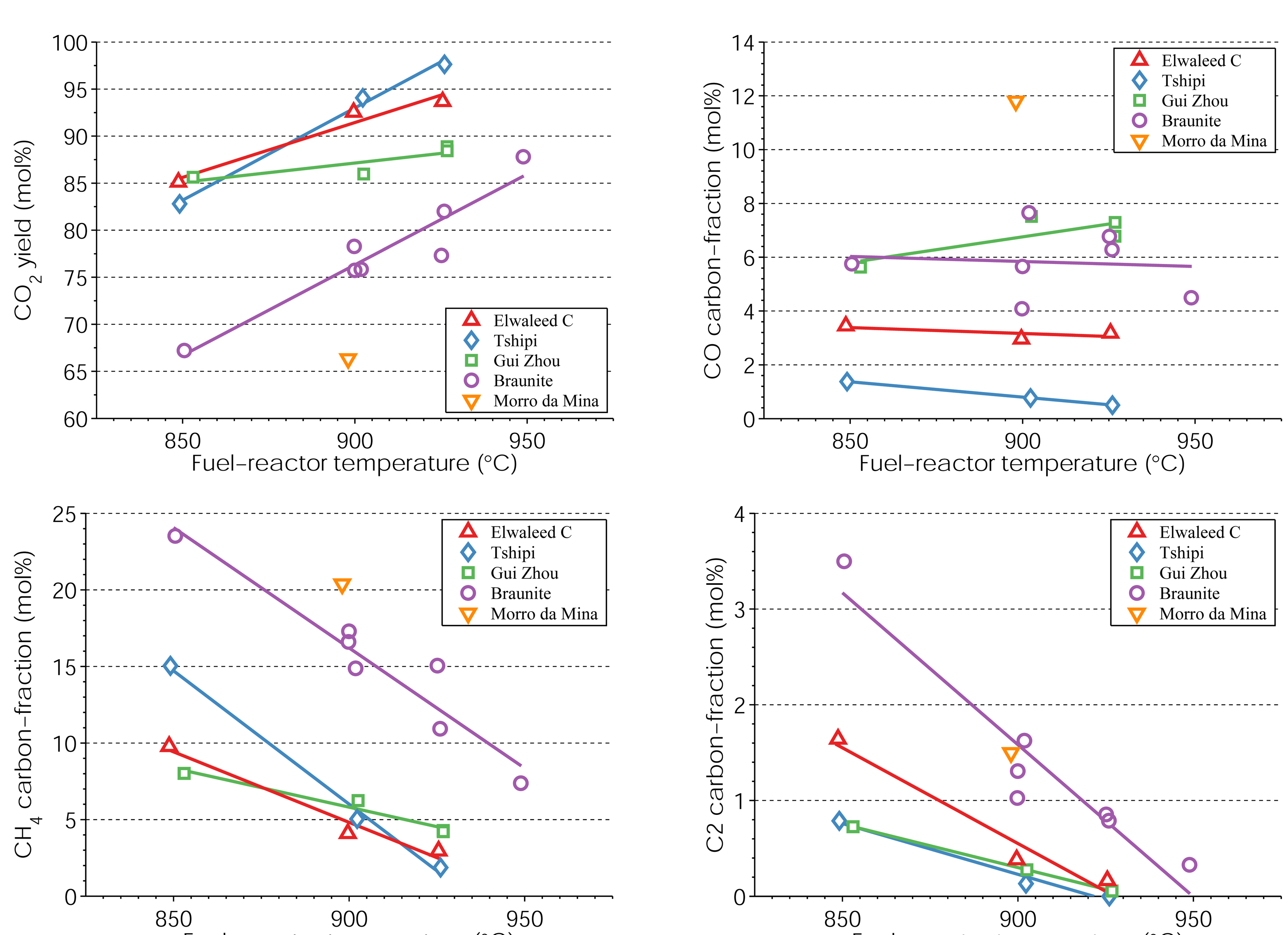
Key results summarized (table above)

- Gui Zhou Mn ore has the best overall properties.
- All ores tested have higher reactivity towards CO than towards CH_4.
- Attrition under redox condition differs from mechanical attrition. Redox attrition is more significant.

Fuel conversion (figures below)

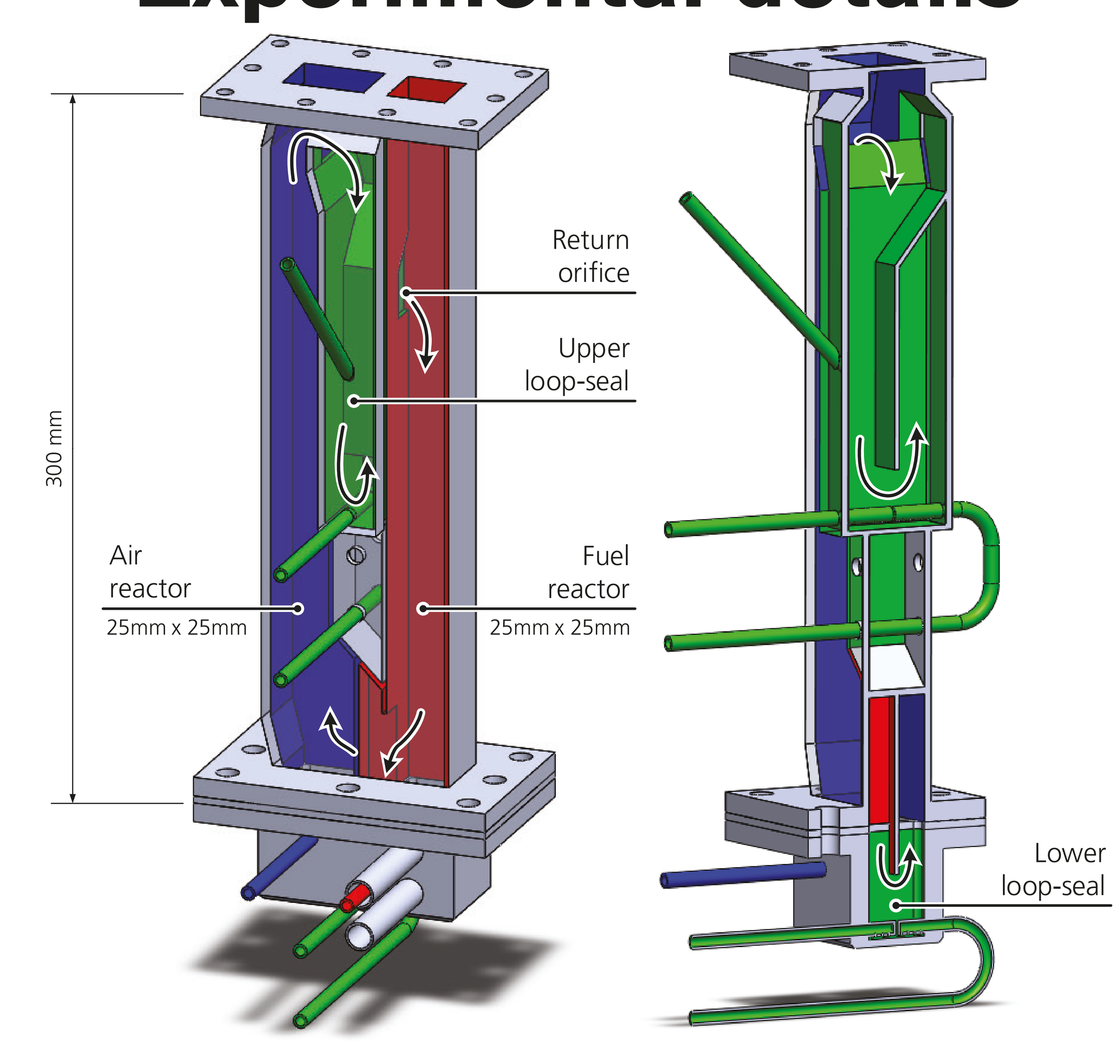
CO_2 yield / carbon fractions: molar amount of fuel carbon converted to CO_2 / CO, CH_4 or C2.

- No C3-species were detected within the conditions investigated.
- Strong decrease of CH_4 and C2 when increasing temperature.
- No clear temperature trend for CO fraction as long as CH_4 and C2 exist. CO is probably an intermediate reaction product.
- Clear increase in CO_2 yield when increasing temperature.



Fuel conversion

Experimental details



300 W chemical-looping reactor

	CLOU →	Biomass volatiles →	Methane →	Syngas (CO/H_2) →	CLOU
Elwaleed C	×	15 h	4 h	9 h	×
Tshipi	×	14 h	n/a	3 h	n/a
Gui Zhou	×	11 h	15 h	6 h	n/a
Braunite	×	16 h	3 h	10 h	×
Morro da Mina	×	7 h	n/a	n/a	n/a

Experiments

Component	Fraction (vol%)	Carbon fraction (atomic %)	LHV (MJ/m_n^3)
CO	43	55.1	12.6
H_2	30	–	10.8
CH_4	20	25.6	35.8
C_2H_4	6	15.4	59.0
C_3H_6	1	3.8	85.9
Total	100	99.9	20.2

Fuel composition

ÅFORSK
European Research Council
Established by the European Commission

The research leading to these results received fundings from Stiftelsen ÅForsk (project 14-379) and from the European Research Council (ERC) under the European Union's Seventh Framework Programme (FP7/2007-2013) (grant agreement No 291235).