BEST
Bioenergy and Sustainable Technologies

BIO-LOOP Chemical Looping for efficient biomass utilization

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COMET Modul: Cooperation project of the Sub-Areas 1.1, 1.2 and 2.1

Introduction

With respect to the climate objectives Chemical Looping (CL) processes constitute a promising alternative to traditional thermochemical conversion routes. Oxygen is supplied to the fuel by solid materials, so-called oxygen carriers (OC), instead of air. Thereby, biomass can be used for hydrogen production (Chemical Looping Hydrogen, CLH) or it can be burnt with simplified CO_2 sequestration (Chemical Looping Combustion, CLC).

BIO-LOOP aims to develop a fixed bed reactor for hydrogen production (sub-project 3) as well as a fluidized bed reactor for heat and power production (sub-project 4). Fundamental research on the OC material and its reactivity is performed in sub-project 1. Sub-project 2 develops a CFD-based multi-physics toolbox to support the overall technology development. The results of the sub-projects are presented.

Project 1: Fundamental experimental and theoretical investigations

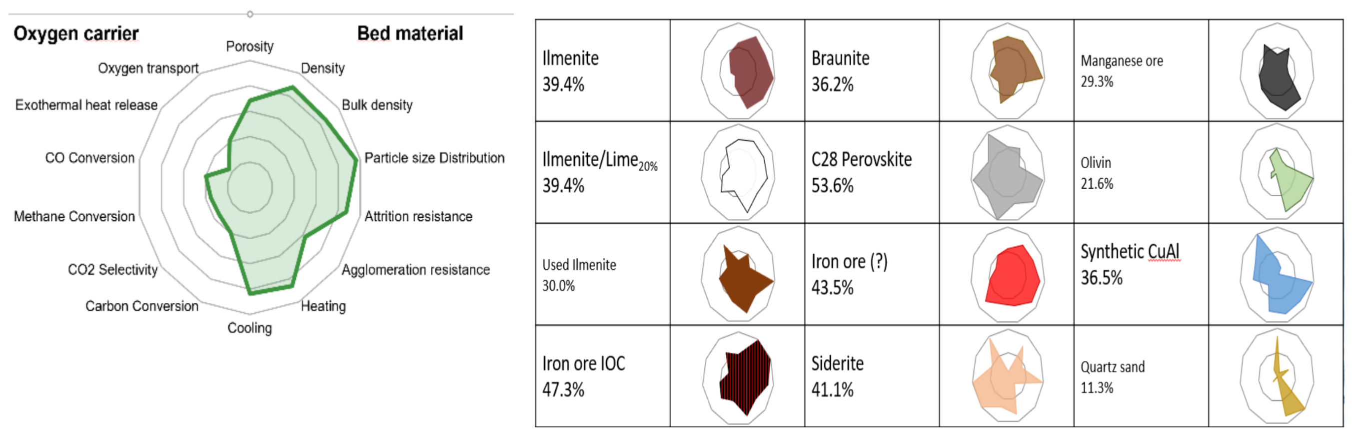

Fig 1: Oxygen carrier properties in spider charts

Since the oxygen carrier represents the key element of the chemical looping technology, its most important properties and process requirements had to be identified, apart from its environmental sustainability and costs. Numerous investigations were necessary for this purpose. Materials were evaluated based on specific OC properties and general bed material properties in experimental campaigns. A comparison was conducted through so-called spider charts (Fig. 1), where the area within the line directly reflects a material's suitability.

Project 2: Development of multi-physics CFD-based simulation toolbox

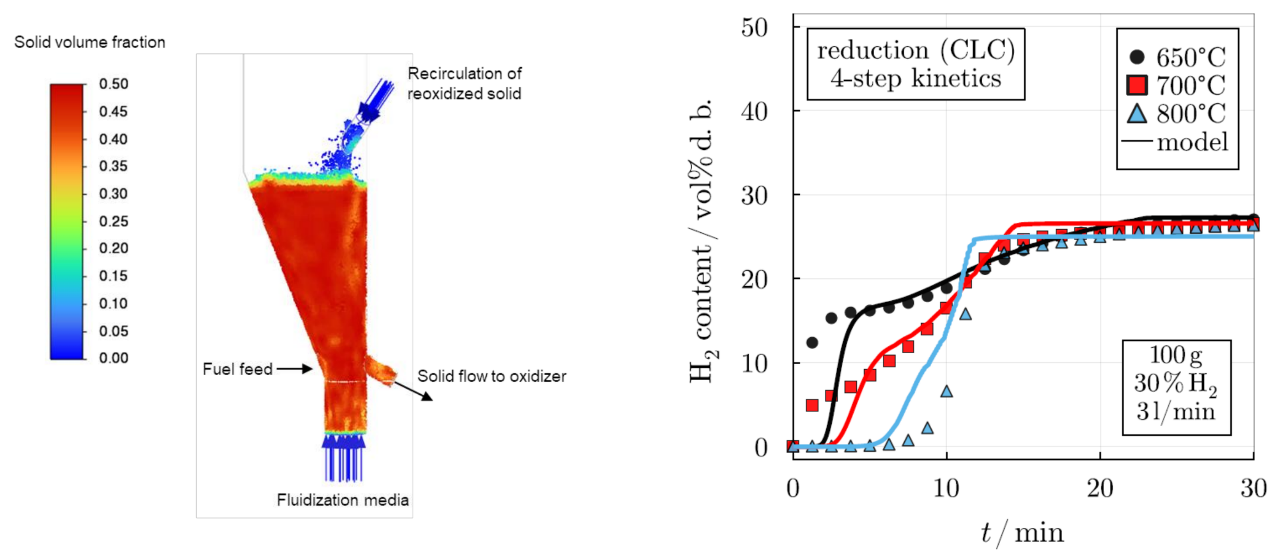

Fig. 2: CFD results of a fluidized bed system (l.) and 1D simulation of a fixed bed systems (r.)

Gas-solid conversion of the OC (or fuel) occurs on three relevant length scales. Chemical reactions between gases and solids constitute the smallest scale. In systems with larger particles (e.g. pellets) gaseous reactants and heat have to be transported into the porous solid structure, leading to a retardation of the conversion process. Countless particles are present at the entire reactor scale, all of which potentially move and interact. Kinetic models, single particle models and a reactor model were developed and coupled to describe the overall process. Experimental results at all three scales were successfully predicted by the final multiscale models (Fig. 2).

Project partners:

- Chalmers University of Technology
- TU Graz (ITE, CEET)
- TU Wien
- NIC Ljubljana
- CSIC Spain
- Rouge H2 Engineering GmbH
- SW-Energie Technik GmbH
- TG Mess-, Steuer- und Regeltechnik GmbH
- Rohkraft- Ing. Karl Pfiehl GmbH
- Aichernig Engineering GmbH
- AVL List GmbH
- Syncraft Engineering GmbH

Project 3: System integration – biomass fixed bed chemical looping technologies

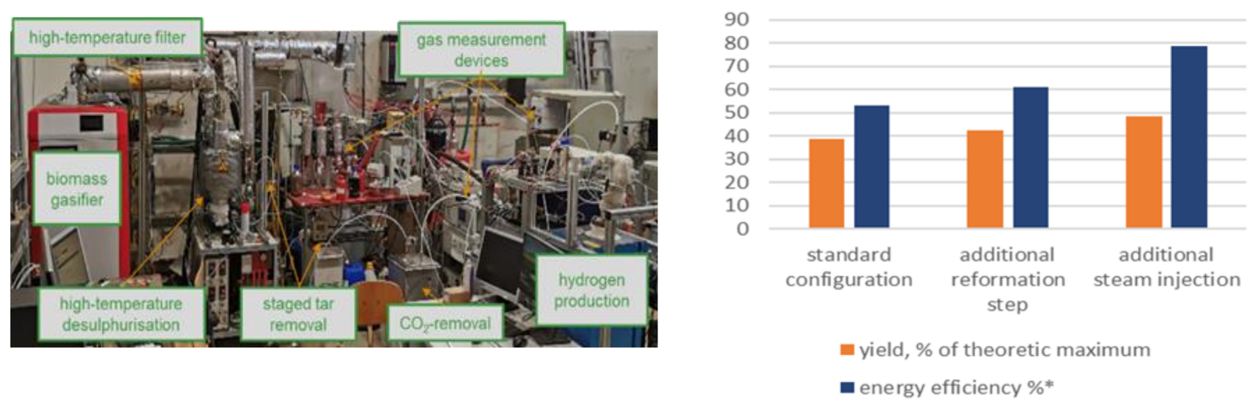

Fig 3: Investigation of the CLH system

The coupling of a fixed bed gasification system and a CLH system was implemented on a pilot scale setup. First, impurities were removed from the generated raw gas and the CO_2 content was reduced (standard configuration). To increase the reducing power of the gas, the setup was supplemented with an additional reformer. The influence of additional steam injection was investigated. An eventual hydrogen purity of 99.9922 vol% was achieved. The hydrogen yield and process efficiency could be improved significantly (Fig. 3).

Project 4: System integration – biomass fluidized bed chemical looping technologies

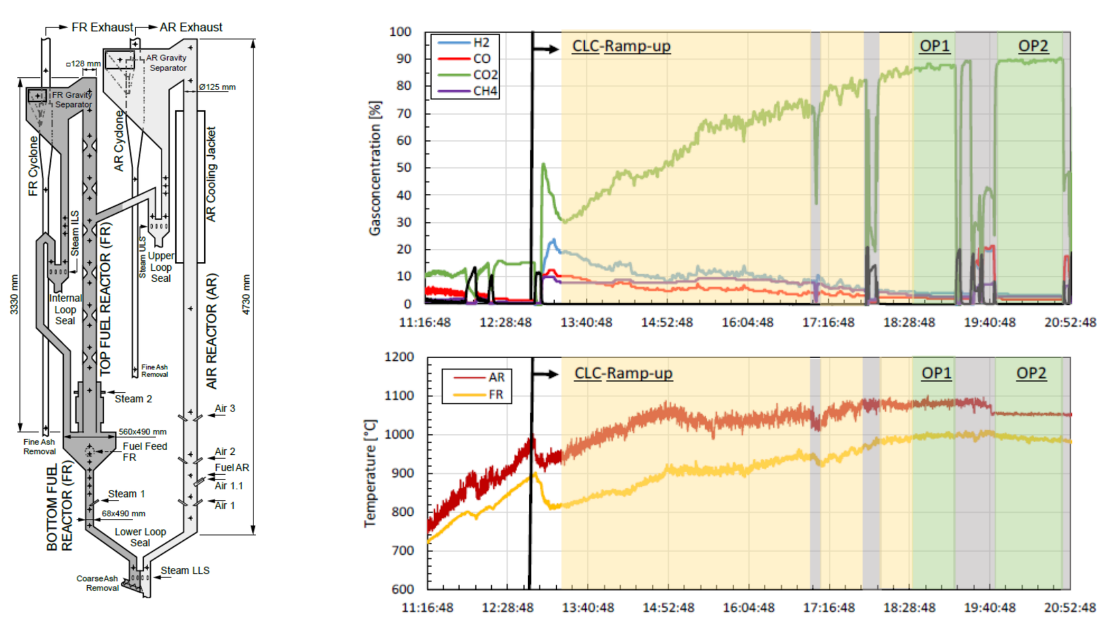

Fig. 4: CLC benchmarks in the DFB pilot plant with ilmenite (limestone as additive)

Stable autothermal operation was successfully carried out in the DFB pilot plant with two fluidized beds – either with natural ilmenite and limestone (Fig. 4) or with a synthetic OC. Furthermore, the influence of parameters such as the process temperature, the carrier circulation rate and the position of the constrictions in the counter current column of the fuel reactor on the CLC process was determined.

In addition, a methodology was developed to determine the formation of ash layers on the particulate oxygen carrier material in an oxidizing atmosphere. With the developed methodology, the growth of the layers on ilmenite was investigated and the influence on relevant oxygen carrier properties was determined.

Acknowledgments

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