Experimental testing of oxygen carriers in a Chemical-Looping Combustion reactor

We are looking for students who are motivated to independently conduct combustion experiments in our chemical-looping, fluidized-bed reactor over a period of 4-6 month. The measured data (gas composition, pressure, temperature) is to be evaluated with the student’s own code (e.g. Matlab or Excel). Additionally, different types of powder analyses are carried out with the oxygen-carrier material before and after the combustion tests. To conclude this project, the results are to be presented (presentation and written report). The work is conducted at the Division of Energy Technology, which is part of the Department of Space, Earth and Environment.

Background – Chemical-Looping Combustion (CLC) is an innovative combustion process, in which the CO₂ from the combustion is obtained as a separate stream. CLC can be used to produce steam for generation of electricity or heat. If the separated CO₂ is compressed and stored underground, CLC can be part of a so-called “carbon capture and storage” (CCS) scheme. The use of fossil fuels in CLC with CO₂ storage would create a carbon neutral process, whereas the use of biomass fuels would result in a reduction of atmospheric CO₂ (“negative CO₂ emissions”).

In Chemical-Looping Combustion, fuel and combustion air, which contains about 80 % of N₂ and only 20 % of O₂, are never mixed. Hence, an expensive and energy-intensive gas separation step can be avoided. The oxygen from the combustion air is transported to the fuel by a so-called oxygen carrier. The oxygen carrier is typically in the form of a powder, which consists of metal-oxide particles in the size range of 100-300 µm. These particles undergo cyclic reactions with the combustion air and the fuel: in the air reactor the oxygen carrier is oxidized, and in the fuel reactor the oxygen carrier is reduced (the fuel, in turn, is oxidized). This principle is visualized in Figure 1.

Aim and method – The aim of the experimental work is to assess and compare the properties of different materials as oxygen carrier. The materials are tested with a syngas (50 % CO / 50 % H₂) and methane (CH₄) at about 850-950 °C and different parameters are varied, for example, temperature, fuel input and oxygen-carrier circulation. This is the main part of the work and will be conducted with a laboratory-scale CLC fluidized-bed reactor, which is operated by the student. The CLC reactor, see Figure 2, is about 30 cm high and is located inside and electric furnace. The logged experiment data is evaluated with a program written by the student (species balances and fluidization-related calculations), for example in Matlab or Excel.

Over the period of a CLC test series, the particles usually become subject to ageing, that is to say a change in their physical and chemical properties (hardness, density, size, material structure, etc.). On the basis of different material analysis methods, the ageing process is quantified and a lifetime can be estimated.

Keywords: Chemical-Looping Combustion (CLC), circulating fluidized-bed (CFB), fluidization, powder technology, material technology, CO₂ separation, sustainable energy technology

Working areas: process engineering, chemical engineering, material technology, mechanical engineering, energy technology

Type and length: research project, Master’s thesis, 4-6 month, starting date flexible

Requirements
- Studies within natural- or engineering sciences
- Ability to work independently and hands-on
- Experienced in data evaluation with Excel or Matlab or similar
- Fluent in spoken and written English
- Laboratory or workshop experience are an advantage

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