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Chemical-Looping Combustion of Solid Fuels – status and recent progress

Anders Lyngfelt* and Carl Linderholm

Department of Energy and Environment, Chalmers University of Technology, S-412 96 Göteborg, Sweden

Abstract

Chemical-Looping Combustion of solid fuels has been studied for ten years and significant progress has been made. The paper discusses operational experiences and various aspects of up-scaling, including similarities to fluidized-bed combustion, key challenges, cost structure and strategies for reducing costs for demonstration. Based on more than 9000 h of CLC operation in 34 pilots, of which >3000 h with solid fuels, it is concluded that there are oxygen carrier materials suitable for solid fuels, and that the technology should be ready for scale-up.

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Keywords: Chemical-Looping Combustion; CO_2 capture;

* Corresponding author. Tel.: +46-31 772 1427; fax: +46-31-772 3592.
E-mail address: Anders.Lyngfelt@chalmers.se

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1. Introduction

1.1. Why Chemical-Looping Combustion ?

Conventional CO_2 capture processes have large costs and energy penalties associated with gas separation. Chemical-looping combustion (CLC) is a new combustion principle that uses metal oxides for oxygen transfer from air to fuel. Thus, fuel can be oxidized without mixing fuel and combustion air and the combustion products, i.e. CO_2 and steam, are recovered in a separate flow without any active gas separation. After condensation of steam essentially pure CO_2 is obtained. Thus, CO_2 capture is inherent in the process and costs and penalties for gas separation may be avoided. Other advantages involve the improved possibilities to reduce emissions of SO_2 and NO_x because the pollutants will be concentrated in the smaller flow from the fuel reactor. This may also apply to ash components known to create difficulties, e.g. alkali in biomass.

1.2. What is Chemical-Looping Combustion ?

The reactor system can be built as a system of two interconnected fluidized beds, the air reactor and the fuel reactor, with an oxygen carrier in the form of a metal oxide circulating between the two beds. The general principle is shown in Figure 1 and an example showing how the process could be designed using the circulating fluidized bed principle for the transfer of particles between the two reactors is shown in Figure 2.

CLC research and development initially had a focus on gaseous fuels, but the last ten years important work has been dedicated to CLC of solid fuels. Technology overviews are given in a number of reviews, e.g. [1-5].

In the case of gaseous fuels, these are introduced through the bottom plate as fluidizing gas, thus achieving a good distribution over the cross-section. As the gas moves upwards through the bed it is gradually converted and if conditions are suitable the gases are fully oxidized to CO_2 and H_2O as they leave the reactor, as shown in pilot testing with gaseous fuels like natural gas [6]. Chemical-looping combustion of solid fuels could use the general circulating fluidized bed (CFB) concept outlined in Figure 2, but the fuel reactor system needs to be adapted for use of solid fuels.

When heated, solid fuels release gaseous combustible compounds (volatiles) that may react with the oxygen carrier to form CO_2 and H_2O. After the release of volatiles there is a remaining char that also needs to be burnt. The reaction between the oxygen-carrier and the char remaining after release of volatiles is not direct, but involves an intermediate gasification step, i.e. C + H_2O => CO + H_2, Figure 3.

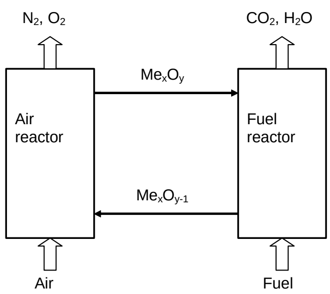

Figure 1. CLC principle. Me_xO_y is the metal oxide circulated.

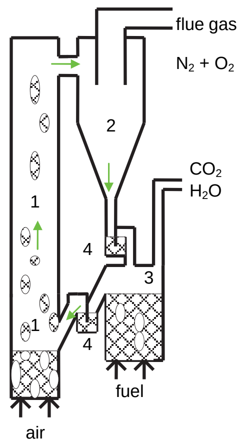

Figure 2. CFB reactor system for gas, 1) air reactor, 2) cyclone, 3) fuel reactor 4) loop seals

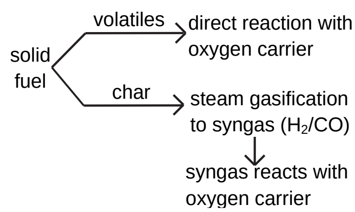

Figure 3. Solid fuel reactions in CLC