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Chemical looping combustion of methane using a copper-based oxygen carrier in a 150 kW reactor system

Øyvind Langørgen[a,]*, Inge Saanum[a], Nils Erland L. Haugen[a]

[a]*SINTEF Energy Research, Sem Sælands vei 11, 7034 Trondheim, Norway*

Abstract

Chemical looping combustion experiments have been conducted in the 150 kW CLC reactor at SINTEF Energy Research in Trondheim with good results. Methane was used as fuel and porous copper oxide based particles, with a bulk density of 800 kg/m^3 were, used as oxygen carrier. At a fuel power of 140 kW the methane conversion was limited to about 90%, but at 100 kW a methane conversion of up to about 98% was achieved with an oxygen deficit of about 3% compared to the stoichiometric amount. At the same time, the specific fuel reactor inventory was just above 120 kg/MW, which is low compared to data found in the literature. The total active inventory in both reactors together was then 44 kg and the overall excess air ratio was about 1.2.

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Keywords: Chemical Looping Combustion; CLC; Carbon Capture and Storage; CCS; Copper Oxygen Carrier; Gaseous Fuel.

1. Introduction

The development of the chemical looping combustion (CLC) technology has been moving forward the later years, but further development is still needed before commercialisation. However, the process is proven in several lab scale and pilot scale setups around the world [1] and successful operation of such systems have been obtained for durations of up to several weeks. The process is a promising CO_2 capture process because of the potentially low

* Corresponding author. Tel.: +47-73-59-72-00; fax: +47-73-59-72-50.
E-mail address: oyvind.langorgen@sintef.no

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energy penalty when the CO_2 capture takes place within the combustion process itself, as well as low CO_2 capture cost [2]. The process can be described as an oxy-fuel process with inherent air separation where a metal oxide is alternately oxidised and reduced, and in this way takes up oxygen from the air and supplies it to the fuel. Much work has been conducted on the development of oxygen carrier materials as it is critical to develop particles with high oxygen transport capacity that at the same time are long lasting and cheap to produce. It is also important to develop reactors that utilize the properties of the particles in the best way. In this work, the special design of the CLC reactor at SINTEF Energy Research in Trondheim is tested with a copper oxide based oxygen carrier.

2. Experimental setup

2.1. Overview of the CLC pilot plant

The CLC reactor system consists of two interconnected circulating fluidized bed reactors as shown in Figure 1. The two reactors, the air and fuel reactor respectively, are interconnected through particle loop seals that works as gas locks to ensure that only the particles are transferred between the reactors. In addition, particles are also transferred from the fuel reactor to the air reactor through the lifter, which is fed from the bottom of the fuel reactor. The air and fuel reactors are 6 m tall of which the first 1 m is a conical bottom section. The remaining 5 m cylindrical sections have an internal diameter of 230 mm and 154 mm, respectively. The system has three particle transport screws, one feeding screw and two extraction screws, which makes it possible to refill and extract particles during operation. The reactors are heated up by hot air and fuel that are introduced into the particle beds, and pilot burners are mounted above the bed to ensure safe ignition of the injected fuel. During CLC operation, the reactor temperature is controlled by adjusting the air preheat temperature to the air reactor. In addition, five cooling panels are mounted within the air reactor. The system is originally designed for operation on methane as fuel gas at a maximum fuel power of 150 kW [3].

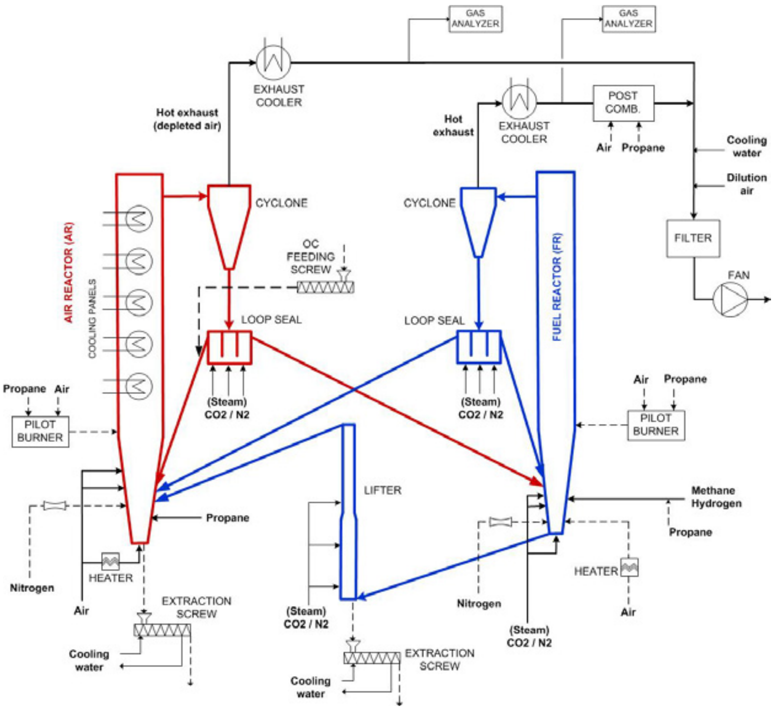

Fig. 1. Reactor system layout.