Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 114 (2017) 317 – 324

Energy Procedia

13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland

Improvement of “near-term” fluidized bed chemical looping combustion for power generation

Junming Fan[a,b], Hui Hong[a] *, Hongguang Jin[a]

[a] *Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, PR China*
[b]*University of Chinese Academy of Sciences, Beijing 100049, PR China*

Abstract

Chemical looping combustion (CLC) is regarded as the “second-generation” CCS for power generation, and it has been mainly focused on to be operated on two interconnected fluidized bed. With the previously abundant and relative matured experience in operating CLC in fluidized bed, power generation from fluidized bed CLC is a “near-term” solution for practical utilization of CLC. In this work, we proposed a novel process by thermally coupled fluidized-bed CLC with advanced supercritical CO_2 cycle (CLC-sCO_2). From the preliminarily results of thermodynamic performance, approximately 6.4 percent points of net electricity efficiency is benefited from this novel process as against that of conventional CLC-steam cycle process, reaching 48.13% close-match to that of a conventional NGCC process with CO_2 capture (49.38%). To further elevate thermal efficiency of CLC-sCO_2, improvements are conducted by operating a low-pressure fluidized bed CLC and replacing one-stage supercritical CO_2 compressor into two-stage intercooling compressors, as can be expected, approximately 2% of additional thermal efficiency is earned in an improved CLC-sCO_2 system. Finally mapping of future CLC power station including “near-term”, “long-term” and future period is included.

© 2017 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the organizing committee of GHGT-13.

Keywords: Chemcial looping combustion, fluidized bed, power generation, CO_2 capture

---

1. Introduction

It is clear and incontrovertible that growth in global population and economic activities will contribute to huge

---

* Corresponding author. Tel.: +86-10-82543031; fax: +86-10-82543031.
E-mail address: honghui@iet.cn

1876-6102 © 2017 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the organizing committee of GHGT-13.
doi:10.1016/j.egypro.2017.03.1173

increase in CO_2 emissions, which may lead to planet temperature rise and irreversible climate change. As expected, if effective methods to mitigate CO_2 emissions are still inefficient, the global CO_2 emissions will be increased from currently ~40 Gt CO_2/yr to ~100 Gt CO_2/yr by 2050 [1]. Chemical looping combustion (CLC) is the most promising technology that has the potential to replace the "first generation" CO_2 capture and storage (CCS) in the future, i.e. pre-combustion, oxy-fuel, and post-combustion. CLC is an attractive option for CO_2 capture because CO_2 is inherently separated from the combustion process, and thus no or little energy is expended to perform CO_2 capture.

CLC was first proposed by Ishida and Jin [2, 3]. During the last three decades, with the continuous R&D efforts, CLC technology has been grown from "proof of concept" to scaling-up pilot plant (maximized to 3 MW_{th} [4]) with the cooperation of many research groups and participating industry companies.

In the latest years, CLC has been mainly focused on two interconnected fluidized bed reactors in order to accomplish the industry application. From previously continuous tests, it has been confirmed the use of interconnected fluidized bed was capable of running CLC. However a major problem related to fluidized bed based CLC is the atmospheric or low-pressure operation. There still have several technical problems to maintain a stable solid circulation between the reactors under pressurized conditions. If fluidized-bed CLC is used for power generation, and not pressurized, CLC integrated with steam cycle is current option for "near-term" CLC power plant. It was estimated a natural-gas fuelled CLC steam cycle power plant acquired a net power efficiency of 40.1% including captured CO_2 compression [5], however by comparison, the power efficiency of a conventional natural gas combined cycle has been approached to 59.62% without CCS at a turbine inlet temperature of 1425 ^oC and a pressure ratio of 20 bar, considering CCS, the efficiency will drop to 49.38% [6]. Therefore it can be revealed that the current fluidized-bed CLC would limit the efficiency of the underlying thermal cycle to that of a steam cycle, rather than a more effective combined cycle [7]. Even though some other reactor configurations have been presented for pressurized operation of CLC, such as alternating packed bed [8] and rotating reactor [9], these design concepts are still far from practical tests in relative to experienced fluidized bed CLC, still needing experimental validated for demonstrating their feasibility on a large scale.

Therefore, for the purpose of future commercialization of CLC for power generation in the near-coming years, improvement of current fluidized bed CLC power station is of importance to make CLC technical feasibility by means of increasing power efficiency. In this work, we first present a novel process by thermal integration of chemical looping combustion with downstream supercritical CO_2 cycle (CLC-sCO_2) instead of current steam cycle. Supercritical CO_2 operated in a closed-loop recompression Brayton cycle, which offers the potential of higher cycle efficiency as against supercritical steam cycle at temperatures relevant to fluidized bed CLC (approximately 900 ^oC). The aim of this study is to evaluate the thermodynamic performance of the CLC-sCO_2 process for power generation. Firstly we present the basic configuration of this novel process; secondly thermodynamic performances of this regarded process vs. conventional CLC integrated steam cycle are conducted; subsequently a sensitivity analysis is involved to examine the process feasibility; finally further improvement is put forward to further increasing the thermal efficiency of the CLC-sCO_2 power generation.

2. Process description

2.1. Fluidized bed chemical looping combustion with supercritical CO_2 cycle(CLC-sCO_2)

Fig. 1 presents the process configuration of the fluidized bed chemical looping combustion thermally coupled with supercritical CO_2 cycle (CLC- sCO_2) for power generation. This novel process mainly consists of three subunits, namely chemical looping combustion system, supercritical CO_2 cycle system, and gases preheating and heat recovery system. As shown, the fuel (CH_4, at atmospheric condition) is fed to the fuel reactor (FR) prior to it being preheated to 246 ^oC via EX1. During this step, the fuel is fully oxidized to CO_2 and H_2O, with corresponding reduction of oxidized oxygen carriers ($NiO/NiAl_2O_4$) to their reduced state ($Ni/NiAl_2O_4$). Subsequently the $Ni/NiAl_2O_4$ particles are transported into the air reactor (AR) by means of gravity force. In the AR, to regenerate oxidized carriers, the reduced ones are re-oxidized with air. Due to heavily exothermic oxidation in the AR, abundant heat will be released, and cooled supercritical CO_2 (527 ^oC, 300 bar) is employed to collect the excessive heat released in the AR. Following, the heated supercritical CO_2 (800 ^oC, 300 bar) is, then, expanded in the turbine, transforming physical energy contained in heated supercritical CO_2 stream to electricity. The exhausted supercritical

Download English Version:

https://daneshyari.com/en/article/5445447

Download Persian Version:

https://daneshyari.com/article/5445447

Daneshyari.com