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Review of chemical looping technology for energy conservation and utilization: CO_2 capture and energy cascade utilization

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ABSTRACT

Chemical looping combustion (CLC) is a promising CO_2 capture technology, which expected to achieve 100% capture efficiency with a low energy penalty. The principle of CLC is utilizing an oxygen carrier as a medium for transporting oxygen between two reactors, aiming to avoid nitrogen in combustion exhaust. This article discusses the advances in chemical looping with a focus on oxygen carriers, reactors, coupling systems, and other applications of CLC concept for solid fuels. The development and design of high performance oxygen carriers and suitable reactors are key factors in the development of CLC technology. The main challenge in scaling up the CLC process is the development of appropriate OCs with optimal properties, including high transport oxygen capacity, reactivity, and stability. Recently, a fair number of hours of continuous operation in pilot plants have instilled the confidence required in further development of this process towards commercialization. The use of solid fuels is gaining momentum, and the liquid fuels need further attention for its development. The integrated systems based on chemical looping technology for poly-generation applications simultaneously achieve the efficient conversion and cascade utilization of chemical energy and CO_2 separation. The article also describes the prospects of the future development in the chemical looping technology, and its viability for industrial deployment.

1. Introduction

Owing to the worldwide dependency on fossil fuels, the amount of exhaust emissions generated in human production and life is increasing day by day. The ensuing air pollution and greenhouse effect have significantly damaged the Earth's ecology, on which humanity relies for its existence. During the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in December 2015, a worldwide consensus was established on drastically lowering energy related CO_2 emissions [1]. According to this purpose, actions need to be taken to enhance energy efficiency, mainly through increased use of renewable energy or carbon capture and storage (CCS) technology to reduce CO_2 emissions [2]. CCS refers to a low-carbon technology which captures CO_2 released from coal and gas for power generation and from other industrial processes and transports it offshore for safe and permanent underground storage [3]. Today, there are three primary forms of CO_2 capture: pre-combustion, post-combustion and oxy-combustion using pure oxygen instead of air as the primary oxidant (see Fig. 1) [4–6]. Post-combustion capture of CO_2 occurs after the burning of fossil fuels. CO_2 is separated from flue gas when it is passed through a liquid which causes a chemical reaction. This is also called scrubbing. Pre-combustion capture is where CO_2 is separated or removed prior to the burning of fossil fuels. The pre-combustion technology converts fossil fuels into a gas made up of CO_2 and Hydrogen (H_2). These gases are then separated, with H_2 used to fuel the power plant. Oxy-combustion burns fossil fuels with nearly pure oxygen. The flue gas produced only contains CO_2 and steam. These are separated by a cooling process with the water condensing leaving a flue gas of almost pure CO_2. Although these technologies reduce carbon dioxide emissions, they are not energy efficient [7]. Therefore, great efforts have been made in the last two decades to reduce the energy penalties accompanying capturing technologies.

Chemical looping combustion (CLC), as a novel and efficient

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