Separation and Purification Technology 337 (2024) 126352

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Review

A review on mercury removal in chemical looping combustion of coal

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ARTICLE INFO

Keywords:
Mercury pollution
Chemical looping combustion
Gasification medium
Gasification product
Oxygen carrier
Reaction temperature
Reactor configuration

ABSTRACT

Chemical looping combustion (CLC) of coal can effective achieve the capture and storage of CO_2, reduce the emission of NO_x, and realize the energy cascade utilization. During the process of CLC, mercury (Hg) will release from coal and enrich in gas. If Hg has not been effectively treated, it will not only cause the serious harm to human body and environment, but also affect the purification and storage of CO_2 by mixing with CO_2, as well as lead to the corrosion of equipment, which highlights the importance of Hg removal in CLC. This review summarized the influence and mechanism of gasification medium (signal CO_2, signal H_2O vapor, as well as mixture of CO_2 and H_2O vapor), gasification products (CO, H_2, NH_3, HCl, and H_2S), oxygen carrier (single metal oxides of Fe_2O_3, MnO_2, Co_3O_4, CuO, and CeO_2, $CaSO_4$, mixed OC, and natural-ores OC), reaction temperature, as well as reactor configuration in fuel reactor and air reactor on the release, oxidation, and transfer of Hg in CLC of coal. Based on these above, several suggestions about the selection of appropriate $H_2O(g)$ content to minimize the release of Hg and promote the oxidation of Hg^0, the selection of OC with weak adsorption capacity and strong oxidation performance, the preparation and application of Cu, Mn, Co spinel structured oxides for promoting the catalytic oxidation of Hg^0 in CLC high-temperature furnace, and the choice of an appropriate air reactor temperature to maximize the oxidation of Hg^0 in the AR and reduce the escape of Hg from the AR outlet were provided for promoting the removal of Hg for CLC in the future.

1. Introduction

The CO_2 released by coal combustion is one of the main reasons for the global warming [1,2]. Chemical looping combustion (CLC) of coal can effectively realize the separation and capture of CO_2 [3,4], which shows significant potential in mitigating the global warming [5]. The system of CLC is shown in Fig. 1, which mainly consists of fuel reactor (FR), air reactor (AR), and oxygen carrier (OC) [6]. At present, CLC of coal mainly has two modes of in-situ gasification chemical looping combustion (iG-CLC) and chemical looping with oxygen uncoupling (CLOU) [7–10]. The main reaction process in FR of iG-CLC and CLOU are demonstrated in Fig. 2 [11]. As for iG-CLC, the whole process is mainly divided into four stages: coal pyrolysis, reaction between OC and pyrolysis gas, coke gasification, reaction between OC and gasification products [12]. In the FR, the coal is firstly heated to pyrolysis, and volatiles including CO, H_2, and CH_4 release from the coal (R1) [13,14], which are subsequently oxidized by OC to produce CO_2 and $H_2O(g)$ (R2) [15]. Char is gasified by gasification mediums of CO_2 and/or $H_2O(g)$ to produce CO and H_2 (R3-R5) [16–18]. OC is used between the FR and the AR for oxidizing CO (R6) and H_2 (R7) to produce CO_2 and $H_2O(g)$. After the condensation unit [19,20], CO_2 and $H_2O(g)$ are separated to obtain high concentration of CO_2 [21–23]. After oxidizing the gasification products of CO and H_2, the OC is reduced and then transferred to the AR to be re-oxidized (R8) by air [24], and finally enters the FR again for recycling [25–28]. Compared with iG-CLC, CLOU uses OC to release O_2 in the FR for the combustion of volatile and fixed carbon [29–33]. Coal does react directly with gaseous oxygen [34], rather than the OC [35], and the whole process does not need gasification reaction [36–38], avoiding the restriction of slow gas–solid gasification rate in the coal gasification process [39–44]. Based on these above, OC is the medium for oxygen transfer between FR and AR [45]. Compared to pure O_2 combustion, as fuel and O_2 are not directly contacted in the whole process, N_2 is inherently separated, thus the cost caused by separating N_2 from air to obtain pure O_2 can be effectively avoided [46]. The one-step reaction of the original fuel and air is divided into two steps in the FR and the AR. By contrast to conventional combustion, on the basis of not

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https://doi.org/10.1016/j.seppur.2024.126352
Received 16 November 2023; Received in revised form 6 January 2024; Accepted 7 January 2024
Available online 11 January 2024
1383-5866/