Applied Energy 215 (2018) 348–355

Contents lists available at ScienceDirect

Applied Energy

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

Coupling coal pyrolysis with char gasification in a multi-stage fluidized bed to co-produce high-quality tar and syngas

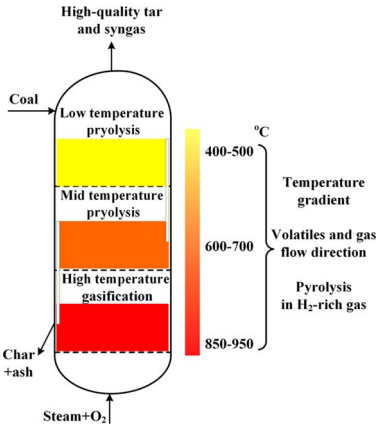
Zhaohui Chen[a,b], Yunjia Li[a], Dengguo Lai[c], Sulong Geng[a], Qi Zhou[d], Shiqiu Gao[a,*], Guangwen Xu[a]

[a] State Key Laboratory of Multi-phase Complex Systems, Institute of Process Engineering, Chinese Academy of Sciences, Beijing 100190, China
[b] Department of Chemical Engineering, Tsinghua University, Beijing 100084, China
[c] Institute of Urban Environment, Chinese Academy of Sciences, Xiamen 361021, China
[d] Beijing Research Institute of Coal Chemistry, Coal Science and Technology Research Institute Co., Ltd., Beijing 100013, China

HIGHLIGHTS

- A multi-stage fluidized bed was proposed to couple coal pyrolysis with char gasification.
- This work succeeded in the smooth operation of multi-stage fluidized bed.
- Char gasification provided heat and gas atmosphere for coal pyrolysis.
- The flow direction of volatile against temperature ascending avoided the deep secondary reaction of tar.
- Coupling pyrolysis and gasification could achieve the coal staged conversion.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Coal pyrolysis
Multi-stage fluidized bed
Tar
Syngas
Char gasification

ABSTRACT

A multi-stage fluidized bed (MSFB) by configuring the distributor with an overflow standpipe between its neighboring stages was developed to couple the powder coal pyrolysis with its resultant char gasification for co-production of tar and syngas. This work succeeded in the smooth operation of MSFB for coal staged conversion. The three modes of coupling pyrolysis and gasification in terms of the one-stage, two-stage and three-stage bed characterized by temperature drop from the bottom up were investigated to evaluate the quality of the liquid and gas products. Coupling low- and mid-temperature tandem coal pyrolysis with high-temperature char gasification in the MSFB improved the quality of tar and syngas. The obtained tar yield was over 80% of the Gray-King assay tar yield and its light tar fraction (boiling point $< 360\,^{\circ}C$) was as high as 70–80% in the MSFB. Syngas with CH_4 content of 5.2 vol.% was produced that was suitable for SNG production. Inside the reactor, the flow direction of pyrolysis volatiles toward the temperature drop avoided the deep secondary reaction of tar. Syngas and steam from the bottom gasification section could contribute to the formation of light tar and CH_4 by affecting the top coal pyrolysis. A comparison with the typical pyrolysis processes suggested that the MSFB process had its own advantages in treating powder coal to produce the high-quality tar and syngas.

* Corresponding author.
E-mail address: sqgao@ipe.ac.cn (S. Gao).

https://doi.org/10.1016/j.apenergy.2018.02.023
Received 10 October 2017; Received in revised form 2 February 2018; Accepted 5 February 2018
0306-2619/ © 2018 Elsevier Ltd. All rights reserved.

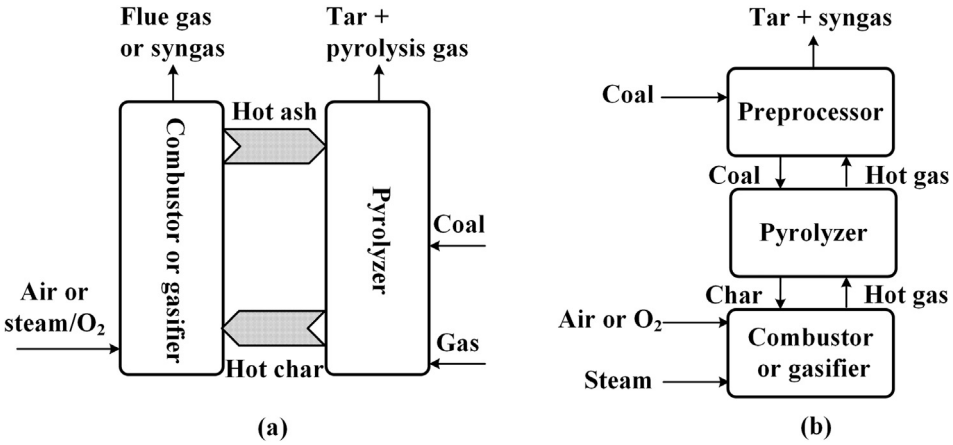


Fig. 1. The principle diagrams of (a) the dual-bed pyrolysis process using solid heat carrier and (b) the pyrolysis process using gas heat carrier.

1. Introduction

China enjoys huge reserves of coal. Low-rank coals covering lignite and subbituminous coal, accounting for more than half of the total reserves, are rich in high value volatiles equivalent to 100 billion tons of the oil and gas resources [1,2]. Special interest has been taken in such a coal conversion technology that can convert high-value part in coal to the scarce liquid and gaseous fuels ahead of gasification or combustion.

Two types of coal pyrolysis processes based on separating coal pyrolysis from char gasification or combustion have been developed to implement the volatiles extraction from coal [3] and their principle diagrams are depicted in Fig. 1. One is a kind of dual-bed pyrolysis process by decoupling coal pyrolysis from char gasification or combustion such as the coal toping process [4,5], the poly-generation technologies combining pyrolysis with combustion [6–8], and the dual-bed pyrolysis and gasification [9], which can separate products from pyrolysis and gasification and suppress their inconducive interactions [3]. Between the two reactors in these processes, the solid heat carrier, usually ash blended with char, from the gasifier or combustor are recycled into the pyrolyzer to provide sensible heat for coal pyrolysis, as shown in Fig. 1(a). The average temperature in both reactors can be optimized by adjusting the solids circulating rate in the process with solid heat carrier. However, the countercurrent flow of solid heat carrier and volatiles causes the remarkable temperature increase of primary volatiles by contacting with high temperature solid heat carrier [10]. The uncontrolled secondary reaction of volatiles has to occur in gas phase and over heat carrier particles to generate heavy components at higher temperature than that required for pyrolysis [10]. Also, the strong mixing between cold coal and hot solid heat carrier in the reactor can promote their heat transfer but generate a great deal of dust. Many pilot tests and industrial demonstrations have proved that coal tar from this kind of process was of poor quality with above 50% of the pitch content and the high dust content [6,10–12], which readily caused the block of pipelines and limited the long-time running of the industrial equipment.

The other pyrolysis process belongs to the gas heat carrier technology by coupling coal pyrolysis with char gasification or combustion such as the Lurgi-Spuelgas (L-S) moving bed pyrolysis process [13], the Lurgi moving bed gasification process [14], the Char Oil Energy Development (COED) fluidized bed pyrolysis process [15] and the Efficient Co-production with Coal Flash Partial Hydro-pyrolysis Technology (ECOPRO) featured by the entrained-flow bed [16], in which the reactions from pyrolysis and gasification are rearranged to facilitate the beneficial interactions (for example, char gasification provides heat and reaction atmosphere for coal pyrolysis). The process using gas heat carrier has a good performance due to the positive effects of gas atmosphere on coal pyrolysis, as shown in Fig. 1(b), and enjoys the high-quality tar as well. However, the moving bed processes such as the L-S pyrolysis process and the Lurgi gasification process can only use lump coal as feedstock [13,14], which limited the source of raw materials in industry. The ECOPRO two-stage entrained-flow bed with an upper fast hydropyrolysis and a bottom slag gasification uses pulverized coal with sizes of below 50 μm [16], which needs the secondary processing of coal with high cost. In the mechanical coal mining process, the output of powder coal below 10 mm accounts for as much as 60% of the total output [17]. At present, the powder coal pyrolysis adopted mainly to the aforementioned solid heat carrier dual-bed process with the poor-quality tar.

With the intention of producing the high-quality tar and syngas from powder coal, we proposed a multi-stage fluidized bed (MSFB) process, which allows to couple coal pyrolysis with char gasification in a single reactor. It consists of two or more stages in fluidized bed with an overflow standpipe between its neighboring stages and operates with the countercurrent flow of coal particles and gasification agents. As shown in Fig. 2, inside the MSFB reactor coal particles flow downward

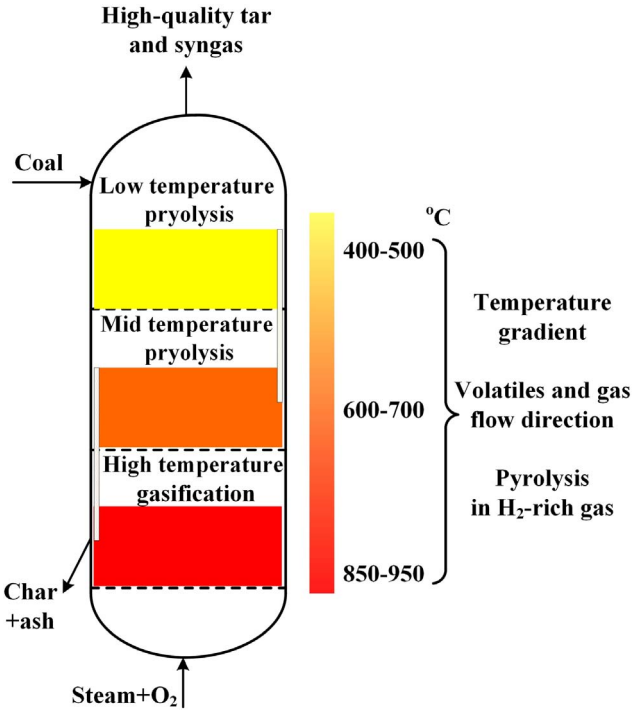


Fig. 2. The principle diagram of the MSFB pyrolysis and gasification.

Download English Version:

https://daneshyari.com/en/article/6680635

Download Persian Version:

https://daneshyari.com/article/6680635

Daneshyari.com