ARTICLE IN PRESS

Applied Energy xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

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

Application and research on Regenerative High Temperature Air Combustion technology on low-rank coal pyrolysis

Pei Pei, Qicheng Wang, Daohong Wu *

Beijing Shenwu Environmental & Energy Technology Co., Ltd, Beijing, China

HIGHLIGHTS

- Based on RHTAC technology, RRTC has been developed, and was adopted by Shenwu Pyrolysis Process (SPP).
- For RRTC, the low calorific value gas fuel can be used and the heat loss in fume exhausted is low.
- The RRTCs can realize accurate temperature control and the separation of volatile materials and fume in the pyrolyzer.
- Tar yield and gas quality is improved. Moreover, SPP could solve some technical problems for low-rank coal pyrolysis.

ARTICLE INFO

Article history:
Received 6 January 2015
Received in revised form 26 June 2015
Accepted 30 June 2015
Available online xxxx

Keywords:
RHTAC
RRTC
SPP
Heat-carrier-free regenerative rotating bed
Low-rank coal
Pyrolysis

ABSTRACT

Regenerative High Temperature Air Combustion (RHTAC) technology is composed of circular-ceramic regenerator, burners, small four-way reversing valve and control system. RHTAC technology works by using the regenerator in burners to complete heat exchange between the high-temperature fume exhausted and the combustion air. Based on RHTAC technology, Regenerative Radiant Tube Combustor (RRTC) has been developed, and was adopted by Shenwu Pyrolysis Process (SPP), which is a new pyrolysis technology with the heat-carrier-free rotating bed. SPP was researched and developed to upgrade low-rank coal into the upgraded coal, tar and pyrolyzing gas. Presently, various coals from China and other countries have been conducted, including Lignite and Long flame coal. To understand the function of the RRTCs in SPP, a pilot plant has been constructed and used to investigate the effects of the RRTCs on the fume and pyrolyzer temperature distributions and pyrolyzing products. The results show that low calorific value gas fuel (>700 kcal/Nm^3) can be used, the heat loss in fume exhausted is low (temp. about 150 °C), so thermal efficiency of the RRTC is greatly improved; the RRTCs can realize accurate temperature control and the separation of volatile materials and fume in the pyrolyzer, so as to increase tar yield and improve gas quality. The tar yield is more than 90% of the Gray-King tar yield; the pyrolyzing gas contains high contents of CH_4, H_2 and CO. Moreover, SPP could solve some technical problems, such as high dust content in coal tar, likely blockage of pipeline and greatly increasing the subsequent tar processing cost.

1. Introduction

According to the International Energy Agency (IEA), the global energy demand is expected to grow at a rate of 1.5% a year by 2030, and the use of coal is expected to rise by over 60% to the year of 2030 [1]. China is the largest coal producer and consumer in the world. In 2014, the coal production amounted to 3.87 billion tons, and the coal consumption amounted to 3.51 billion tons, which accounts about 66.0% of the primary energy resources consumption. It is clear that coal has played a crucial role in China's economic growth. At the same time, China's net oil import amounted to 308 million tons, accounting for 59% of total petroleum consumption, which has threatened the China's energy security. The declining energy supplies and severe environmental constraints associated with fossil fuels worldwide demonstrate that coal as an affluent non-renewable resource in China is far more important than oil, gas and other energy resources. Aiming to alleviate the pressure for environmental capacity and energy security problem, clean and highly efficient utilization of coal has been becoming a core issue for China. Especially, with the sharp decrease in the availability of high-rank coal resources, the highly efficient conversion of low-rank coal has become even more essential [2,3].

* Corresponding author. Tel.: +86 010 60751999.
E-mail address: sw@shenwu.com.cn (D. Wu).

http://dx.doi.org/10.1016/j.apenergy.2015.06.070
0306-2619/

Please cite this article in press as: Pei P et al. Application and research on Regenerative High Temperature Air Combustion technology on low-rank coal pyrolysis. Appl Energy (2015), http://dx.doi.org/10.1016/j.apenergy.2015.06.070

It is estimated that nearly half of the world's coal reserves consist of low-rank coal. In China, the resources of low-rank coal are also abundant. Unfortunately, because of its low energy density and typically high moisture content, low-rank coal is not utilized extensively compared to high-rank coal [4]. Pyrolysis, a method of upgrading for low-rank coal, is of great significance to utilize low-rank coal cleanly and efficiently [5,6]. By far, many pyrolysis technologies have been developed to upgrade low-rank coal and meanwhile coproduce tar in some of the technologies. The typical technologies have Toscoal [7], LFC [8], COED [9], Rammler and Luigi [10], Garrett [11], ECOPRO [12], DG [13], MRF et al. [14,15]. Some of them have been commercially demonstrated at a capacity of above 1000 t/d coal, but now there is not any pyrolysis plant in commercial running. Many technical problems about this have been reported, for instance, extending the adaptability of raw coal and the capacity of single furnace, improving tar yield and gas calorific value, reducing the high dust content in coal tar and the influence of heat carrier on gas composition, enhancing the accurate temperature control and the uniform temperature distribution in the pyrolyzer. The most typical technical problem of these is the high fraction of heavy components such as pitch in the produced tar, which means not only the low quality of tar and its difficulty in downstream utilization but implies as well the troubles in running continuously the pyrolysis process due to the deposition of heavy tar on the ducts after the pyrolyzer.

To solve the problems of the pyrolysis technologies mentioned above [7–15], in this study, Regenerative Radiant Tube Combustor (RRTC) has been researched based on the Regenerative High Temperature Air Combustion (RHTAC) technology. And a new pyrolysis process [16], Shenwu Pyrolysis Process (SPP), was developed as the RRTCs were introduced to a rotating bed with heat-carrier-free. To understand the function of the RRTCs, a pilot plant has been constructed and the results from pilot plant facility of SPP will be presented to investigate the effects of the RRTCs on the fume, pyrolyzer temperature distribution and pyrolyzing products.

2. Experimental

2.1. Theory of RHTAC technology and RRTC in SPP

RHTAC technology is composed of circular-ceramic regenerator, burners, small four-way reversing valve and control system. As shown in Fig. 1, RHTAC technology works using the regenerator in burners to complete heat exchange between the high-temperature fume exhausted and the combustion air, in the meanwhile achieves high thermal efficiency, saving energy and low emissions as well. Regenerator is made of special ceramics, which is characterized as large surface for heat exchanging, good heat conductivity and heat resistance. Based on the RHTAC technology, the regenerative burners are installed on both sides of radiant tube in pairs to finish the RRTC (Fig. 2). For any pair of regenerative burners, while one burner is doing combustion, the other is absorbing the heat of fume. After a fixed time, two burners are switched that the combustion one changes to do absorption and the absorption one changes to do combustion. This cycle is repeated constantly. Therefore, the RRTCs can be installed flexible, improve thermal efficiency of pyrolyzer, improve reacting temperature of pyrolyzer with the low calorific value fuel (as low as 700 kcal/Nm^3), achieve low oxygen and low nitrogen combustion, and reduce haze.

2.2. SPP pilot plant and processing

SPP pilot plant with 2 t/h capacity of the low-rank coal includes coal pretreatment unit, regenerative rotating bed pyrolyzer, cooling unit and coke quenching unit. As shown in Fig. 3, the particle sizes of the raw coals are crushed and shaped to 10–100 mm. After drying, the moisture of the coals is reduced into 10 wt.%. Then, the dry coals are well distributed in the rotating bed pyrolyzer through the screw charging machine and then heated up to target temperature after passing through the preheating and reacting zones. In the rotating bed pyrolyzer, the RRTCs have been installed specially on the wall to provide heat for pyrolysis reaction by the combusting low calorific value gas (>700 kcal/Nm^3). In the pyrolyzer, the coal decomposes into the pyrolyzing gas, tar and upgraded coals. The pyrolyzing gas and tar are poured out from the top of pyrolyzer as the gas mixtures, and then gas and tar are separated from each other by the cooler. The upgraded coals are outputted through the screw charging machine and transferred into the product bin after cooling as the solid product. The pyrolyzing gas can be recycled into the rotating bed as the fuel of the RRTCs. Moreover, the hydrogen from the pyrolyzing gas can be extracted through the PSA technology and then used in chemical industry. The tar is sent to the tanks, after hydrogenation, to produce more valuable petrochemicals such as gasoline, diesel or heavy fuel oil.

At present, various coals have been conducted in SPP pilot plant, including Lignite and Long flame coal. The characteristic of Lignite coal sample used in the experiments has been shown in Table 1. The results of the proximate and ultimate analysis and calorific value analysis illustrate that the moisture content of the Lignite is 31.13 wt.%, which is much higher than that of Long flame coal. The content of the volatile matter in the coal samples is 31.99 wt.%. As a result of the analyzing the calorific value of the air dried coal sample, the lower heating value is 4827.10 kcal/kg.

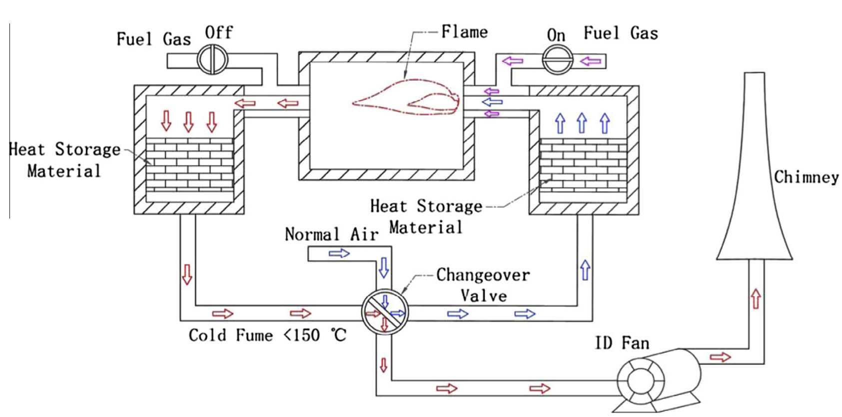

Fig. 1. Scheme for RHTAC technology.

Please cite this article in press as: Pei P et al. Application and research on Regenerative High Temperature Air Combustion technology on low-rank coal pyrolysis. Appl Energy (2015), http://dx.doi.org/10.1016/j.apenergy.2015.06.070