Journal of the Energy Institute xxx (2017) 1–11

Contents lists available at ScienceDirect

Journal of the Energy Institute

journal homepage: http://www.journals.elsevier.com/journal-of-the-energy-institute

Full-scale simulation of flow field in ammonia-based wet flue gas desulfurization double tower

Q4 Qi Zhang*, Shijie Wang, Ping Zhu, Zhiyong Wang, Gu Zhang

Hubei Key Laboratory of Coal Conversion and New Carbon Material, Wuhan University of Science and Technology, Wuhan 430081, Hubei, China

ARTICLE INFO

Article history:
Received 3 September 2016
Received in revised form
15 February 2017
Accepted 21 February 2017
Available online xxx

Keywords:
Ammonia-based WFGD
Sintering flue gas
Double tower
Full-scale simulation
Flow spray

ABSTRACT

With the increasingly strict environmental requirements, sintering flue gas desulfurization in double tower had been applied to improve desulfurization efficiency and reduce the “ammonia escape” and “aerosol” phenomena. In this work, the operating conditions of a sintering plant were simulated by ANSYS CFX and the flow fields without and with fluid spray of a full-scale ammonia-based wet flue gas desulfurization (WFGD) double tower were investigated. According to the results, the evaporating tower had a profound cooling effect on flue gas with spray. The gas flow distribution was non-uniform in evaporating tower, which needed further optimizations. The flow with spray was more uniform in both towers. The pressure drop mainly took place in absorption areas of desulfurization tower. The velocity of inlet region with spray was lower than that without spray in desulfurization tower. The temperature decreased along with the forward direction of gas flow due to the heat transfer with spray in desulfurization tower. The study provided useful data for further optimization in order to achieve high desulfurization efficiency.

© 2017 Energy Institute. Published by Elsevier Ltd. All rights reserved.

UNCORRECTED PROOF

1. Introduction

Sulfur dioxide (SO_2) is the main cause of global environmental problems such as air pollution and acid rain [1]. China is the world's largest steel producer and consumer. The latest statistics from World Steel Association showed that the world steel production was 136 million tons and the production in China reached 69.5 million in June 2016. As a result, the SO_2 emissions in China were also increasingly serious. According to latest data from the Ministry of Environmental Protection in China, the SO_2 emission in iron and steel industry accounted for 10.4% of the total industrial emissions, second only to thermal power industry [2]. The SO_2 emissions from sintering process accounted for approximate 70% of the total iron and steel industrial emissions [3]. With the increasingly strict requirements of environmental protection, the SO_2 removal from sintering flue gas has been a major target in China [4,5].

Compared with various WFGD processes, ammonia-based WFGD has drawn increasing attention in China in recent years due to its lower investment, higher desulfurization efficiency, no secondary pollution and useful byproducts [6]. However, it is not mature in large-scale sintering plants. “Ammonia escapes” and “aerosol” phenomenon were serious that may cause abnormal operations of desulfurization devices and lead to unacceptable high particle concentrations of exhaust gases [7]. To optimize operating conditions, it is of great practical value to study the flow field of the ammonia-based WFGD system.

Strock and Gohara studied the flow field in the spray tower that was eight times smaller than the actual by means of experimentations [8]. Since then, studies of SO_2 absorption with ammonia were conducted by several researchers [9]. With the help of computer technology combined with fluid dynamics, CFD has been developed and used to study the transport behavior in two or three phase flows [10–12]. Gomez et al. [13] first simulated a full-scale FGD plant based on an Euler–Euler approach for the multiphase flow in the combined packed- and spray tower absorber. Jia et al. [14,15] developed a mathematical model according to the double film theory to study the ammonia-based WFGD process in the spray scrubber, and the theoretical results agree with the experimental ones from two 220 t/h boilers in China. This model provided predictions of the absorption performance and appeared to be helpful for designing scrubbers for SO_2 absorption with

---

* Corresponding author.
E-mail addresses: 13163288117@163.com (Q. Zhang), shijie_wang@163.com (S. Wang), mailofzp@163.com (P. Zhu), 15623873526@163.com (Z. Wang), zj2543@163.com (G. Zhang).

http://dx.doi.org/10.1016/j.joei.2017.02.010
1743-9671/© 2017 Energy Institute. Published by Elsevier Ltd. All rights reserved.

Please cite this article in press as: Q. Zhang, et al., Full-scale simulation of flow field in ammonia-based wet flue gas desulfurization double tower, Journal of the Energy Institute (2017), http://dx.doi.org/10.1016/j.joei.2017.02.010

ammonia absorbent. Liu [16] studied the ammonia-based WFGD process in thermal power plant by using Aspen Plus. Peng et al. [17] proposes a non-equilibrium stage model for SO_2 absorption with aqueous ammonia solutions in flue gas based on the two-film mass transfer theory. Li et al. [18] developed a mass-heat transfer and instantaneous chemical reaction model to calculate the desulfurization efficiency of the ammonia-based WFGD in Fluent. Wang et al. [19] developed a detailed model to simulate the gas–liquid flow field in a single tower of full-scale ammonia-based WFGD in a sintering plant by using ANSYS CFX.

However, the previous studies on ammonia-based WFGD system were based on lab scale device or single tower, which had certain limitations on industrialized application. WFGD in double tower has become a trend in recent years, which has better desulfurization efficiency and can reduce "ammonia escape" and "aerosol" phenomena. In addition, previous researches focused mainly on coal-fired boiler flue gas, while the sintering flue gas of iron and steel industry has a larger and unstable gas flow rate, a higher CO concentration and exhaust temperature, a lower SO_2 concentration and changeable contents of moisture and oxygen, which increases the difficulty of sintering flue gas desulfurization.

In this work, the practical equipment sizes and operating conditions of the sintering plant were simulated and the flow field of a full-scale ammonia-based WFGD double tower was studied by using ANSYS CFX software. The aim of this study is to investigate the characteristics of gas–liquid flow field in WFGD double tower and obtain great useful data for further optimization and industrialization.

2. Physical model

Simplified structures of the evaporating tower (at left) and desulfurization tower (at right) based on plant data were presented in Fig. 1. As indicated by arrows in the figure, the high temperature sintering flue gas firstly entered the evaporating tower from the top of the evaporating tower to make a co-current contact with the ammonium sulfate ($(NH_4)_2SO_4$) slurry that was sprayed from the spray layer with 88 nozzles. During the process, the flue gas was cooled, dusted and humidified while the slurry was heated, evaporated and concentrated in the tower, and eventually the concentrated slurry was sent to the crystallization system. At the same time, a small percentage SO_2 of the flue gas was absorbed by spray slurry, and the impurities in flue gas such as dust deposited continuously when contacted with slurry droplets. Then the flue gas left evaporating tower and entered the desulfurization tower at 10° angle from the bottom of the tower. The gas was partially purified and uniformly distributed after packing through the absorption packing layer, then it diffused upwards to make a counter-current contact with the slurry from there spray layers (102 nozzles each layer), which could greatly absorbed the acid gases such as SO_2 and CO_2 in the sintering flue gas. Then the gas entered the washing packing layer for further purification. Finally, it left from the top of the tower after passing through the demister, which was designed to reduce the water content and acid mist. Meanwhile, the slurry fell into the slurry tank for further circulation.

3. Numerical simulation

3.1. Fundamental assumptions

Some assumptions were made to investigate the processes in WFGD tower:

a) The gas components were: 380 ppm SO_2, 210 ppm NO, 0.548% CO, 5.7% CO_2, 15% O_2, 10% H_2O and 68.694% N_2. The gas phase was considered as an incompressible Newtonian fluid.

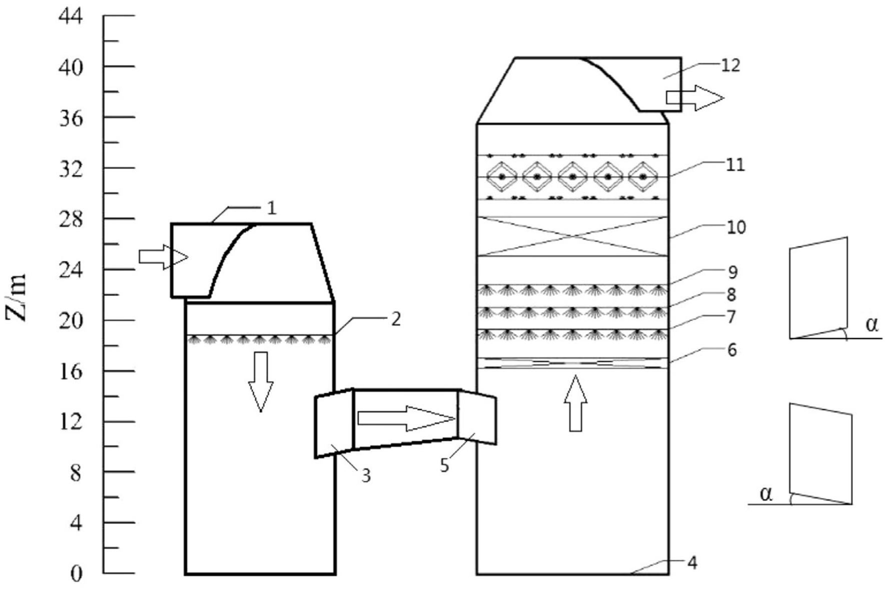

Fig. 1. Simplified structures of the evaporating tower (d = 11.5 m) and desulfurization tower (d = 15 m). In evaporating tower: (1) gas inlet; (2) spray layer (z = 18.7 m); (3) gas outlet (α = 10°). In desulfurization tower: (4) slurry level; (5) gas inlet (α = 10°); (6) absorption packing layer; (7) the first pray layer (z = 19.3 m); (8) the second pray layer (z = 21.1 m); (9) the third pray layer (z = 22.9 m); (10) water wash packing layer; (11) demister; (12) gas outlet.

Please cite this article in press as: Q. Zhang, et al., Full-scale simulation of flow field in ammonia-based wet flue gas desulfurization double tower, Journal of the Energy Institute (2017), http://dx.doi.org/10.1016/j.joei.2017.02.010

Download English Version:

https://daneshyari.com/en/article/8108552

Download Persian Version:

https://daneshyari.com/article/8108552

Daneshyari.com