Chemical Engineering and Processing 62 (2012) 159–167

Contents lists available at SciVerse ScienceDirect

Chemical Engineering and Processing: Process Intensification

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

Dust removal and desulphurization in a novel venturi scrubber

T. Mi, X.M. Yu*

Hubei Key Laboratory of Industrial Fume and Dust Pollution Control, School of Chemical and Environmental Engineering, Jianghan University, Wuhan 430056, PR China

ARTICLE INFO

Article history:
Received 21 May 2011
Received in revised form 17 July 2012
Accepted 18 July 2012
Available online 25 July 2012

Keywords:
Dust collection
Desulphurization
Venturi scrubber
Pressure drop

ABSTRACT

Based on basic geometric structure about venturi scrubber, a novel venturi scrubber was developed. The performance of the novel venturi scrubber was evaluated experimentally by means of pressure drop, dust collection efficiency and desulphurization efficiency in this paper. Firstly, characteristic of pressure drop was studied in the venturi scrubber; a simplified empirical correlation for pressure drop as a function of gas throat velocity and liquid-to-gas ratio was presented. The model has excellent agreement with experimental data. Secondly, the experimental study on dust collection and desulphurization from simulated flue gas was also performed in the scrubber. The results show the venturi scrubber has higher efficiency of dust collection and desulphurization, a relatively lower pressure drop and a stable operation, and can be used for dust collection and gaseous pollutant absorption in the small and medium-sized coal-fired boilers.

1. Introduction

Scrubbing by a liquid spraying is one of the most effective processes used to collect fine particles and soluble gas pollutants from gaseous streams. There are numerous configurations of scrubbers and scrubbing systems designed to provide good contact between the liquid and dirty gas stream for effectively capturing particles or gases, such as spray plates, packed bed towers, jet scrubbers, cyclones, vortex type and venturi scrubbers. Among these, venturi scrubbers are a highly efficient gas-cleaning device that uses a liquid in the form of droplets to remove particles between 0.5 and 10 μm in diameter and gaseous pollutants from industrial exhaust sources [1–4]. In recent decades, venturi scrubbers have been paid intensive attention to removal of fine particulate matters from gaseous streams. Compared with electrostatic precipitators, venturi scrubbers have reliable operation, can treat hot, explosive or harmful gas and sticky particles, and resist corrosive acids and bases [5].

Due to these some advantages such as higher collection efficiency of fine particles, lower initial investment cost, no moving parts, compact volume and easy installation and maintenance, venturi scrubbers were brought in China in the early 1970s, and widely used for flue gas purification for low-capacity coal-fired boilers at power stations. Gradually, they were also widely used for removing respirable dusts [6,7] and toxic gaseous [8] at workplaces with high respirable dust concentration, such as mines and chemical plants. The simultaneous removal of dusts and gaseous pollutants should be considered as the main advantage of venturi scrubbers against other air pollution control systems. In spite of all the aforementioned advantages, the major disadvantage of venturi scrubbers, compared with the other dust collectors, is its higher pressure drop. Pressure drop of venturi scrubbers is typically in the range from 100 to 150 mm H_2O [9]. For high energy venturi scrubbers, they usually have a significant pressure drop ranging from 300 to 900 mmH_2O [10].

Nowadays, SO_2 emission from coal combustion is about 90% of the total SO_2 emissions in China. SO_2 emission causes severely air pollution and is one of the important factors that restrict sustainable development in China. At present, flue gas desulphurization (FGD) technologies with China intellectual property rights have been gradually developed. These FGD technologies have been successfully applied in high-capacity power stations. Due to its high investment and operational cost, these FGD technologies are not suitable for simultaneous removal of dust and SO_2 in flue gas from low and medium-capacity coal-fired boilers, which exist largely in China. Therefore, it is necessary to develop FGD technologies and equipments with simultaneous removal of dusts and sulphuric dioxide in flue gas from industrial coal-fired boilers and furnaces.

2. Features of the novel venturi scrubber and apparatus

Based on basic geometric structure about venturi scrubber [11–15], a novel venturi scrubber was developed [16]. This venturi is composed of shuttle-shaped components. These shuttle-shaped components were assembled to form gas passages similar to a convergent section, a throat section and a divergent section in venturis. These gas passages are equivalent to parallel combination of many

* Corresponding author.
E-mail address: xmyu@jhun.edu.cn (X.M. Yu).

0255-2701/$ – see front matter © 2012 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.cep.2012.07.010

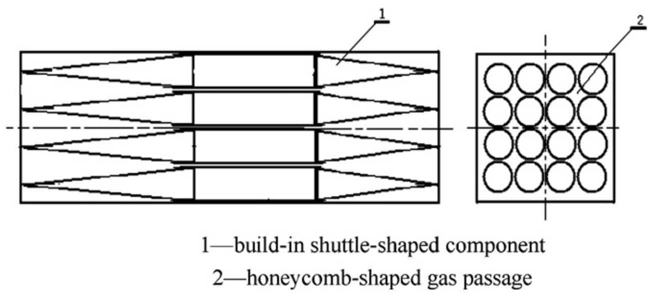

Fig. 1. Diagram of the shuttle-shaped components in the venturi.

venturi scrubbers. On the one hand, the number and size of shuttle-shaped component could be adjusted and selected conveniently with change of the actual operation condition and gas flow rate, because the throat diameter exceeds 420 mm, it is impossible to provide a uniform distribution of the scrubbing droplet over the throat at larger sizes [15]. Compared with usual round or rectangle throat section, due to the symmetrical structure of shuttle-shaped component and the irregular throat cross section, gas–liquid contact area and turbulence intensity of the c stream are enlarged; the flow pressure at the same cross-sectional area is uniform. This arrangement is in favor of uniform distribution of gas stream and spray droplet at the throat section of the venturi scrubber, and it is helpful for dust collision, coagulation and gaseous pollutants absorption. Therefore, the purification efficiency in the scrubber is improved. The schematic of the novel venturi scrubber is shown in Fig. 1. Physical diagrams are shown in Figs. 2 and 3.

In a scrubbing system, several parameters such as pressure drop and dust collection efficiency play important roles in capturing particles and scrubbing harmful gases. Generally, the performance of a novel gas scrubbing equipment is evaluated by means of pressure drop, efficiency of dust collection and gas absorption. The pressure drop is directly related to the operational cost. The optimum design is for achieving the maximum efficiency of dust collection and gas absorption with the minimum pressure drop. For determining the main operational parameters such as pressure drop, dust collection and desulphurization efficiency in the novel venturi scrubber, a pilot rig of the venturi scrubber with a 4000 m^3/h gas flow rate has been set up and shown in Fig. 4.

This study primarily attempts to present the optimal configuration of the novel venturi scrubber, to evaluate feasibility of the novel venturi scrubber for removal of dust and SO_2 from flue gas by several variables such as pressure drop, gas throat velocity, liquid-to-gas ratio, dust concentration, dust size and regeneration solution pH, and so on, in the pilot rig.

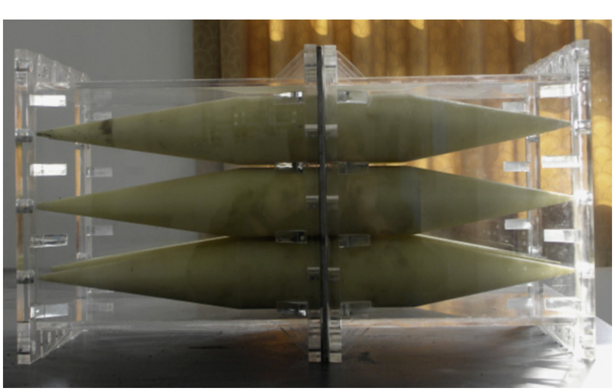

Fig. 2. Appearance of the shuttle-shaped components in the venturi.

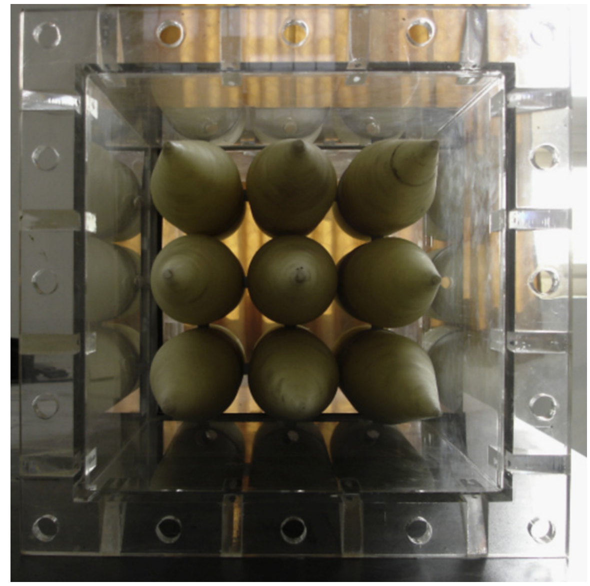

Fig. 3. Entrance structure of the honeycomb-shaped structure in the venturi.

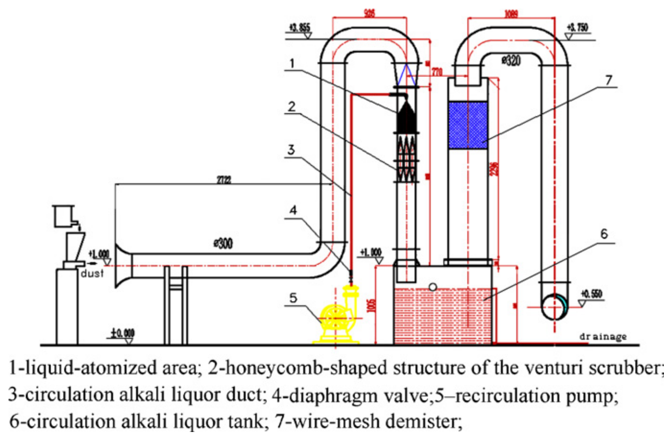

Fig. 4. Pilot rig of the venturi scrubber. (1) Liquid-atomized area; (2) honeycomb-shaped structure of the venturi scrubber; (3) circulation alkali liquor duct; (4) diaphragm valve; (5) recirculation pump; (6) circulation alkali liquor tank; (7) wire-mesh demister.

3. Methodology

The pilot rig consists of an induced fan, a gas regulator, a muffler, gas ducts (300 mm in diameter), the novel venturi scrubber, a water injection system, u-shaped manometers, a dust generator and a SO_2 generator.

When the induced fan started up, gas stream containing dust and SO_2 was driven and passed through induced pipe and the venturi scrubber, successively. Most of dust and SO_2 are removed simultaneously from gas stream in the venturi scrubber. Dusty wastewater is discharged vertically down along the duct to an alkali liquor tank for recycling, and the purified gas is demisted by wire-mesh demister and discharged into the atmosphere through a chimney.

To meet monitoring technical specifications, sampling taps were installed in the inlet and the outlet of gas duct, respectively. The distances between sampling tap in the inlet of gas duct and entrance of the novel venturi scrubber, end of the venturi scrubber and sampling tap in the outlet gas duct are 3700 mm and 3200 mm, respectively. The two sampling taps were used to measure static pressure of gas stream, dust concentration and SO_2 concentration. The amount of dust collected and sulphur dioxide absorbed