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ScienceDirect
Aerosol Science 39 (2008) 1079 – 1088
Journal of Aerosol Science
www.elsevier.com/locate/jaerosci

Development and application of a novel swirl cyclone scrubber—(1) Experimental

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Received 30 November 2007; received in revised form 22 April 2008; accepted 22 July 2008

Abstract

Conventional cyclones have a lower collection efficiency for smaller particles and conventional wet scrubbers have significant clogging and fouling problems by salt formation at the tip, the inside and outside of the nozzles, the tubes and the walls of scrubbers. Also, many companies and manufacturing sites have been in trouble for collecting their adhesive particulates. The novel swirl scrubber that we have developed consists mainly of a cyclone and a swirl scrubber with an impact cone and plates. This study reports the collection efficiency of particulates and the application of the novel swirl scrubber. The particle collection efficiency as a function of particle size was investigated with changes of plate angles, nozzle size and pressure, and volumetric flow rate of scrubbing medium. The particle collection efficiency increased with a decrease in plate angle, an increase in pressure of scrubbing medium at the nozzle tip, and an increase in volumetric flow rate of the scrubbing medium. The collection efficiency of PM_{10} by scrubbing effect was much higher than that by cyclonic effect. In particular, the total increase in particle collection efficiency by scrubbing effect was significant (around 2.5 μm) in particle aerodynamic diameter. The developed novel swirl scrubber can be used for significantly increasing the collection efficiency of TSP, PM_{10}, and $PM_{2.5}$, in particular, which have adhesive characteristics. The costs for installation, operation and maintenance of the scrubber system are much cheaper than those of cyclones and scrubbers or other particulate collecting devices.

Keywords: Swirl; Scrubbing; Cyclone; Plate; Sticky particles

1. Introduction

Cyclones have been very useful as pre-cleaning devices of particles which are larger than 10 μm in their aerodynamic diameter. However, it is not easy to get a higher collection efficiency than 90% with conventional cyclones if the particle size is not larger than 25 μm. Even though advanced high-efficiency cyclones could get a collection efficiency of approximately 70% down to 5 μm particles, the efficiency rapidly decreases with a size decrease in particles (Wark, Warner, & Davis, 1998; Yoshida, Ono, & Fukui, 2005). The significant pressure loss and operation cost increase accompanied by improving collection efficiency of particles are also other drawbacks of cyclones.

Wet scrubbers have been popularly used for the collection of acidic gases, mists, and particles with significantly reducing risks of fire, explosion and erosion (Chien & Chu, 2000; Deshwal et al., 2008; Jin, Deshwal, Park, & Lee, 2006;

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0021-8502/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jaerosci.2008.07.010

Li & Cai, 2006). Since wet scrubbers use mostly water for the scrubbing of particulate matter (Park, Jung, Jung, Lee, & Lee, 2005), it is very common to have water pollution problems by insufficient treatment, visible plume problems at stacks and freezing problems of scrubbing medium under cold weather situations during winter. Conventional wet scrubbers also have significant clogging and fouling problems by salt formation at the tip, the inside and outside of the nozzles, the tubes and the walls of scrubbers. Other disadvantages of conventional wet scrubbing systems are the expensive costs for treatment or disposal of sludge and high operation cost incurred as a result of the improvement of control efficiency (Kim, Jung, Oh, & Lee, 2001; Meikap & Biswas, 2004).

Many companies and manufacturing sites have been in trouble for collecting their adhesive particulates, such as tars and mists with high temperature. Increased costs for control of particulate matter and sludge have also been a heavy burden for many companies. Therefore, it is necessary to develop a cheap and effective control device of particulate matters that have acidic and sticky properties.

There have been many reports on improving the performance or application of wet scrubbers and/or cyclones (Chang, Chi, & Chang-Chien, 2004; Dwari, Biswas, & Meikap, 2004; Gemci & Ebert, 1992; Laitinen, Hautanen, & Keskinen, 1997; Li & Cai, 2004, 2006; Meikap, Kundu, & Biswas, 2002; Pei, 1996; Schwarz, Smolík, Veselý, Sýkorová, & Kučera, 1996; Xu, Guo, Kaneko, & Kato, 2000; Yang, Jung, Wang, & Hsieh, 2005; Yang & Yoshida, 2004; Yoshida, Yoshikawa, Fukui, & Yamamoto, 2008). A swirl promoter scrubber to improve the aerosol deposition in a venturi scrubber has been developed by Mayinger and Lehner (1995). There are a few available studies to deal with sticky particles (Hasler & Nussbaumer, 1999; Li & Cai, 2006; Li, Rudolph, & Peukert, 2006; Maury, Murphy, Kumar, Shi, & Lee, 2005; Müller, Peukert, Polke, & Stenger, 2004; Peukert & Wadenpohl, 2001).

We have developed a novel swirl scrubber that mainly consists of a cyclone and a swirl scrubber with a rod impact plate and swirl plates to overcome the many drawbacks of conventional cyclones and wet scrubbers (Yang & Yoshida, 2004). This paper reports on the development, the collection efficiency analysis of particulate matter and the application of the novel swirl scrubber systems. Theoretical analyses for the swirl scrubber systems are presented in the sister paper of this paper (Park & Lee, 2008).

2. Novel swirl cyclone scrubber system

Fig. 1 shows a schematic of a system analyzing collection efficiency of particles using the novel swirl cyclone scrubber (NSCS) that we have developed. The NSCS system consists of mainly a cyclone, swirl plates, a scrubber, feeding and circulation devices of scrubbing medium, and demister. After gas stream including particulate matter passes through the cyclone zone, it enters the swirl plate zones and then experiences the wet scrubber zone.

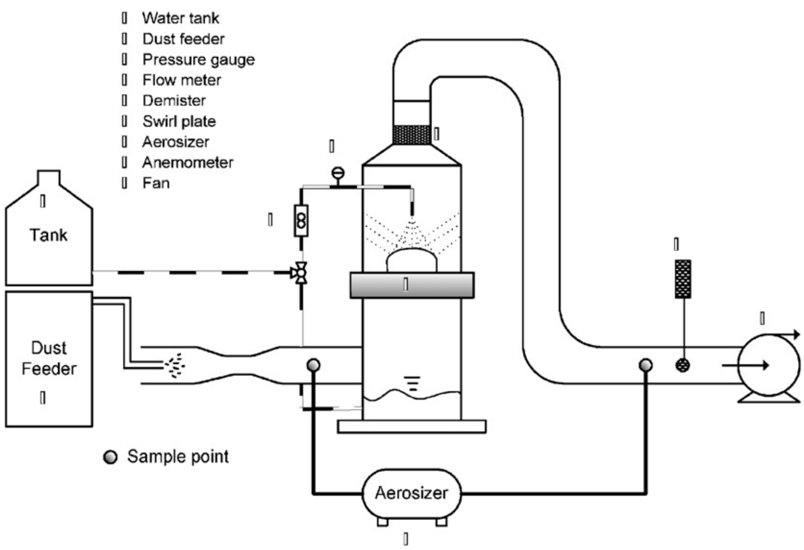

Fig. 1. A schematic of the system analyzing collection efficiency of particles using the novel swirl cyclone scrubber (NSCS).