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Effect of cone installation in a pleated filter cartridge during pulse-jet cleaning

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ABSTRACT

This study investigated the pressure inside a pleated filter cartridge and the dust cleaning efficiency when normal and cylindrical cones were installed in a cartridge during a pulse-jet process. An experimental pulse-jet pleated filter dust collector was designed. The static pressures at three points along the length of the pleated filter cartridge were measured and compared before and after the cartridge was installed with cones. Various parameters, including tank pressure, nozzle diameter and jet distance, were investigated. The pressure drop of the filter cartridge and the dust emission concentration were also studied. This study has demonstrated that the increase in tank pressure improves pulse-jet intensity regardless of the presence of cones in the cartridge. Pulse-jet intensity is also enhanced when the cartridge is installed with either type of cone. Pulse-jet uniformity is reduced for normal cone but increased for cylindrical cone. The effect of cones on pulse-jet pressure is verified by operating performance during dust clogging and cleaning in clean-on-demand mode. The residual pressure drop is decreased, and the peak concentration of dust emission is increased when the normal or cylindrical cone is installed in the cartridge. A cylindrical cone extends the cleaning interval and reduces the dust emission, while the normal cone accomplishes the opposite.

1. Introduction

Pulse-jet pleated filter dust collectors are widely used for cleaning dust laden air in industrial processes [1–3]. Compared with a flat bag filter, a pleated filter has a folded structure and more filtration area. The pressure drop of the filter grows with the accumulation of collected dusts, and it is necessary to clean the filter for stable operation. Pulse-jet cleaning is an effective and widely used method for the filter regeneration [4–8], while the folded structure and limited flexibility of a pleated filter cartridge performs more poorly in dust cleaning than flat-sheet filter bags, producing significantly incomplete filter cleaning or "patchy cleaning" [9–11]. The first noticeable trait of patchy cleaning is that some parts of the pleated filter cartridge are cleaned while some parts still contain residual dust. In addition to intensity, the uniformity of pulse-jet pressures along the length of the filter is an important cause of patchy cleaning [9,11].

In flat bag filters, pleated filters or ceramic filter cartridges, many methods [8,11–14] have been proposed to improve the pulse-jet cleaning efficiency. Yan et al. [11] examined the static pressure distribution along the surface of filter cartridges during the pulse-jet cleaning process; they reduced incomplete cleaning and realized a more stable operation of the dust collector using a supersonic nozzle and an air diffuser. Chi et al. [8] found that the gap between the nozzle and diffuser is important to avoid incomplete cleaning and to enhance the cleaning potential for a ceramic filter cartridge. Ju et al. [12,13] found that an induced nozzle can enhance the pressure distribution inside the cartridge and improve pulse-jet cleaning efficiency. Hao and Diao [14] invented a velocity-difference nozzle, achieved a more uniform pressure along the filter bag, enhanced the pulse-jet cleaning efficiency and extended filter lifetime.

Those methods were developed by modifying nozzle structure and position to improve pulse-jet cleaning efficiency. This paper focuses on the effects of two cones (i.e., normal and cylindrical) installed in a pleated filter cartridge during pulse-jet cleaning. An experimental pulse-jet pleated filter dust collector was designed. The static pressures at three points along the length of the pleated filter cartridge were measured at various tank pressures, nozzle diameters and jet distances before and after the installation of the cones. The pressure drop of the filter cartridge and the dust emission concentration were also studied. The results are useful for the design and improvement of pulse-jet cleaning dust collectors.

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2. Experimental

2.1. Experimental apparatus

A schematic view of the test rig is shown in Fig. 1. The dimension of the filtration chamber is 750 mm (width) × 750 mm (depth) × 1000 mm (height), and one filter cartridge can be installed in the chamber. In the experiment, the pleated filter is wood pulp fiber supported by a rigid wire cage. Parameters of the cartridge are listed in Table 1. The experimental system primarily includes a dust feeder (LSC-6 type with a range of 0–450 g/min and error less than 3%), a pressure tank (26.5 L), an electromagnetic pulse valve (DMF-Z-25 type with an orifice size of 25 mm, inlet and outlet ports diameters of 30 mm. This valve is installed in the pulse tube with an inner diameter of 27 mm), a pulse controller (CQ-B-DCYC type with a pulse duration range of 0.02–0.99 s), a high-frequency pressure acquisition subsystem (piezoelectric pressure transducers of MYD-1540B type with a range of 0–100 kPa, MYD-1540C type with a range of 0–1 MPa, a sensitivity of 8–12 pC/kPa, inherent frequency of 40 kHz; electric charge amplifiers of MCA-02 type; a data acquisition card of MYPCI4526 type), a differential pressure recorder (AZ82012 type with a range of 0–6.895 kPa, an accuracy of 6.895 Pa (0.001 psi)), an online dust monitoring detector (DFM/ZY type with a range of 0–50 mg/m^3), and a frequency conversion fan (SS2-043-1.5 K type). The DFM/ZY type online dust monitoring detector used in this study is based on alternating current electrostatic induction technology, with the measuring probe installed perpendicularly to the direction of the air flow in the exhaust windpipe of the dust collector. The actuated signal is generated when the dust particle collides with the probe and the signal is conversed into the dust concentration value. This signal is directly recorded by the computer.

The operation process of the experimental system can be described as follows. Under the action of the exhaust fan, air is sucked into the dust collector from the downside entrance and flows out through the upside exit (Fig. 1). The outlet of the dust feeder is inserted into the dust collector entrance. Dust can be entrained by the air flow into the filtration chamber and be collected on the outside surface of the filter cartridge. The opening and duration time of the pulse valve is controlled by the pulse controller. The pulse airflow from the pressure tank flows into the filter cartridge through the nozzle when the pulse valve is opened, and the dust on the filter surface is deposited into the hopper. The speed of the fan is controlled by a combination of the air flow meter and the frequency converter to maintain a constant airflow in the dust collector.

Table 1
Parameters of the pleated filter cartridge.

Parameter	Value
Pleat number (n, dimensionless)	118
Pleat pitch (*W*, mm)	8.5
Pleat height (*H*, mm)	40
Inner diameter (D_{in}, mm)	240
Outer diameter (D_{out}, mm)	320
Filter length (*L*, mm)	660
Filter area (A_f, m^2)	6.23
Thickness of filter medium (mm)	0.75
Air permeability (1/m^2·s)	80–100

2.2. Dust

In this research, coal dust was collected after crushing and grinding. The particle size distribution was D_{10} = 6.34 μm, D_{25} = 14.27 μm, D_{50} = 29.27 μm, D_{75} = 51.45 μm, and D_{90} = 69.27 μm. During dust clogging, the dust mass flow rate was set to be 54.6 g/min (i.e., 200 rad/min of the dust feeder), and the air volume flow rate was set to be 7.23 m^3/min (i.e., 40 Hz of the frequency converter in the initial unclogged condition). Then, the superficial filtration velocity was calculated to be 1.93 cm/s, and the dust concentration in the collector entrance was 7.55 g/m^3.

2.3. Experimental design

Firstly, a high-frequency pressure sensor was installed 10 mm below the nozzle (point P0 in Fig. 1) to measure the transient pressure at the nozzle outlet during pulse-jet process. This sensor was then removed after this measurement.

To investigate the pulse-jet effect on the filter cartridge, the static pressures during pulse-jet process were measured using three high-frequency pressure sensors installed on the inner surface of the cartridge; installation positions were at P1 = 100 mm, P2 = 330 mm, and P3 = 560 mm deep from the cartridge opening. Normal and cylindrical cones were designed to improve the pulse-jet pressure inside the filter cartridge. For the normal cone, its wall was rolled up by aluminum sheet and the bottom surface was also sealed with aluminum sheet. The normal cone was hollow. For the cylindrical cone, the top conical part was made of solid wood and the cylindrical part was also rolled up with aluminum sheet. Their surfaces were painted smoothly. Their

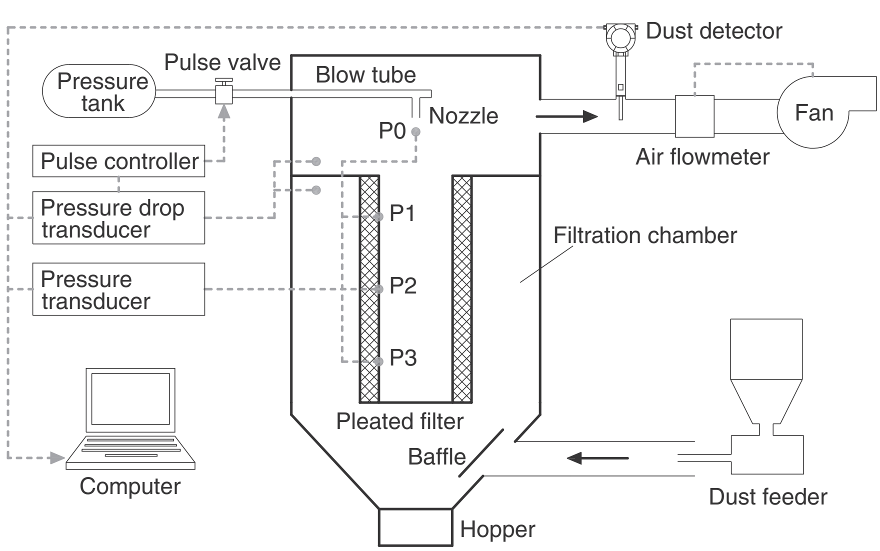

Fig. 1. Schematic view of the test rig.