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The relationship between peak pressure and residual dust of a pulse-jet cartridge filter

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ABSTRACT

To understand the relationship between peak pressure and residual dust of a pulse-jet cartridge filter, the impact of filtration velocity, jetting pressure and nozzle diameter on cleaning effect of the pulse-jet cartridge filter was examined in a semi industrial pulse-jet cartridge filter using several pleated filter cartridges (Φ350 × 1000 mm). The filter was made of polyester and was coated with PTFE (Poly Tetra Fluoro Ethylene) membrane. Results show that filtration velocity could significantly affect the systematic resistance and the residual dust cakes. The smaller the filtration velocity, the less the residual dust cakes and the smaller the systematic resistance. The residual dust cakes are closely related to the peak pressure inside the filter cartridge. After pulse-jet cleaning, the bigger the peak pressures, the less the residual dust is. However, when the peak pressure increases to a certain threshold, the influence of filtration velocity on the dust-cleaning effect is no longer obvious. By curve fitting, the relations between peak pressures and residual dust cakes at a filtration velocity of 0.6, 0.8 and 1.0 m/min are: $y = 1.0715e$ ^ $(-0.0004x)$, $y = 1.4043e$ ^ $(-0.0005x)$ and $y = 1.5476e$ ^ $(-0.0005x)$, respectively. Experimental results indicate that the peak pressure is a valid and reliable index for evaluating the dust-cleaning effect of a pulse-jet cartridge filter.

1. Introduction

Pulse-jet filtration is recognized as the most efficient method of room-temperature gas cleaning to control particulate emissions in order to conform to strict environmental legislation [1]. Owing to their low pressure drop and good filtration efficiency, the pleated fabric filters are considered to be superior to flat-sheet filter bags. Therefore, cartridge filters are widely applied to control particulate emission and recover valuable particles in many industries such as plasma-aided manufacturing and bulk solids processing [1–3]. However, due to the multiple plait structure, the deposition of dust inside the pleats leads to the difficulty in dust cleaning, which is much harder than the flat-sheet filter bags [4]. Furthermore, the dust cake dislodgement will greatly influence the cleaning performance and the systematic resistance [5,6]. Therefore, in order to improve the dust-cleaning effect of pulse-jet cartridge filters, numerous studies have been reported on the structure design and the evaluation indicators. Reports [1,7–15] show that the main performance parameters which impact the pulse-jet cleaning of the cartridge filters are: tank pressure, nozzle diameter, venture tube, pulse duration, and jet distance (the distance between nozzle and cartridge opening). There are another four indexes can be used to evaluate the dust-cleaning intensity of the pulse-jet cartridge filter: peak pressure [1,5,7,11,16], initial pressure rise rate [5,6], reverse acceleration of fabric [3,15] and average pulse overpressure [1,4].

However, the construction and fabric flexibility of pleated filter cartridges lead to less deformation than flat-sheet filter bags during pulse jet cleaning [4]. Therefore, the fabric acceleration is mainly used to evaluate the vibration strength of flexible filtering material instead of the filter cartridges. Yan et al. [4] and Lo et al. [1] pointed out that the average peak pulse pressure on the filter cartridge surface is more closely correlated to cleaning than to overpressure. Besides, Lu et al. [12] concluded that pressure impulse inside the bag would greatly influence the cleaning efficiency, and the parameters affecting the pressure impulse distributions were also discussed. Yi et al. [17] also pointed out that the impulse density could be used as an evaluation index of dust-cleaning effect of the filter bags. However, whether the pressure impulse and the impulse density are suitable for cartridge filters or not is unknown. Considering these factors mentioned above, in this study, the peak pressure was used as an evaluation index for dust-cleaning effect of pulse-jet cartridge filters. Lo et al. [1] and Humphries et al. [16] have pointed out that the peak pressure is an important index to evaluate the dust-cleaning effect, the greater peak pressure of the inner wall of the filter cartridge, the greater force of the dust separation, and thus the better dust-cleaning effect. Moreover, the peak pressure had been used as an index to evaluate the dust-cleaning effect in our previous researches [4,5,10–12,14,18], and the experimental results were consistent with the results of numerical simulations.

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However, it is still inconclusive how the peak pressure affects the cleaning performance as well as how much the force required for cake detachment. For pleated fabric filter cartridges, after pulse-jet cleaning, the residual dust cakes on the filter medium are the most direct reference to indicate the dust-cleaning effect. If the relationship between the residual dust cakes and the peak pressures can be established, then the dust-cleaning effect of a cartridge filter can be predicted. As a result, the dust-cleaning system and operating conditions can be optimized to facilitate the industrial production and ensure the stability of dust-cleaning system.

Based on the research and analysis above, in this study, a series of experiments were carried out to study the relationship between residual dust cakes and peak pressures. Firstly, peak pressures of the filter cartridge (Φ350 × 1000 mm) were tested by three high precision pressure transducers, then the residual dust cakes were obtained from a semi industrial pulse-jet cartridge filter. Finally, the relations between peak pressures and residual dust were established by curve fitting. The purpose of this study is providing theoretical basis and practical guidance for optimizing the dust-cleaning system of a pulse-jet cartridge filter.

2. Test of peak pressures

2.1. Test facilities

A schematic diagram of the pulse-jet experimental equipment is shown in Fig. 1. The experimental setup consists of a compressed air supplying system, a test rig for pulse-jet cleaning performance experiment and a data acquisition system. Compressed air is provided by screw compressors (UD18A-7, Chengdu, China). The cleaning pulse of the compressed air is kept at constant by pressurized air reservoir (volume, 40 L) and is controlled by a pulse valve (DMF-ZM-50s type with diameter 2″). The cartridge (Φ350 × 1000 mm) in Fig. 1, made by polyester and coated with PTFE, was placed on the shelf. The data acquisition system included three pressure transducers (QSY8115), an electric charge amplifier (QSY7709), a portable data acquisition instrument (QSY-USB-8512E) and a computer (Installed the dasView2.0 data processing software). Besides, a manual lifting platform (LNPE, Mianyang, China) was used to adjust the distance between the nozzle and the filter cartridge.

2.2. Test methods

In order to measure the peak pressures of the sidewalls of the filter cartridge, three high precision pressure transducers were used to monitor the peak pressures inside the cartridge, located 100, 500 and 900 mm away from the top of the cartridge, named as points (1)–(3), respectively. The size of the pressure transducers was far smaller than that of the filter cartridge. Thus, the effect of the pressure transducers on the airflow could be ignored. Export signals from the pressure transducer were connected to the import signal from the charge amplifier. The outlet of the charge amplifier was then linked to the inlet of the data acquisition instrument. Finally, the export signal from the data acquisition instrument was linked to the computer. The sampling rate of data acquisition is 1 kHz. In the data analysis phase, Microsoft dasView 2.0 was employed to acquire and change the data into the pressure data based on sensor sensitivity as illustrated in Formula (1) as follows:

$$P = \frac{V}{K_1 K_2} \quad (1)$$

where, P (MPa) is the measured pressure; v (mV) is the voltage output value; K_1 (mv/pC) is the multiple of the charge amplifier; and K_2 (pC/MPa) is the sensor sensitivity.

According to the experimental results of Chen et al. [14,18] and the parameters in engineering application, the dust-cleaning effect is more satisfied when the distance (the distance between nozzle and cartridge opening) is 200 mm, thus the experimental design are as follows:

Three nozzle diameters (25, 28 and 30 mm) and four pulse pressures (0.3, 0.4, 0.5 and 0.6 MPa) were chosen to test the filter cartridge for its effectiveness. The jet distance was a constant (200 mm). For each set of experiment, six values were tested and the average was calculated as the final peak pressure of the filter cartridge.

2.3. Results and discussion

The peak pressures obtained at a jet distance of 200 mm with different nozzle diameters and different pulse pressures are shown in Table 1.

From Table 1, for all the pulse pressures and nozzle diameters, the peak pressures on the filter surface increase from point (1) to point (3). This trend agrees with the results obtained by Chen et al. [14] and Lo et al. [1]. It is also found that in Table 1, under the same pulse pressure, with the increase of nozzle diameter, the average peak pressure increases gradually. This is because the increase of nozzle diameter will lead to the increase of nozzle area, which results in an increase of nozzle exit airflow and induced airflow. This agrees with the results of Chen et al. [4,14] and Lu et al. [12]. Table 1 also shows that the peak pressure of measuring point (1) of 25 mm nozzle diameter is slightly larger than that of 28 mm nozzle diameter under the same pulse pressure. This is because the decrease of the nozzle diameter increases the airflow

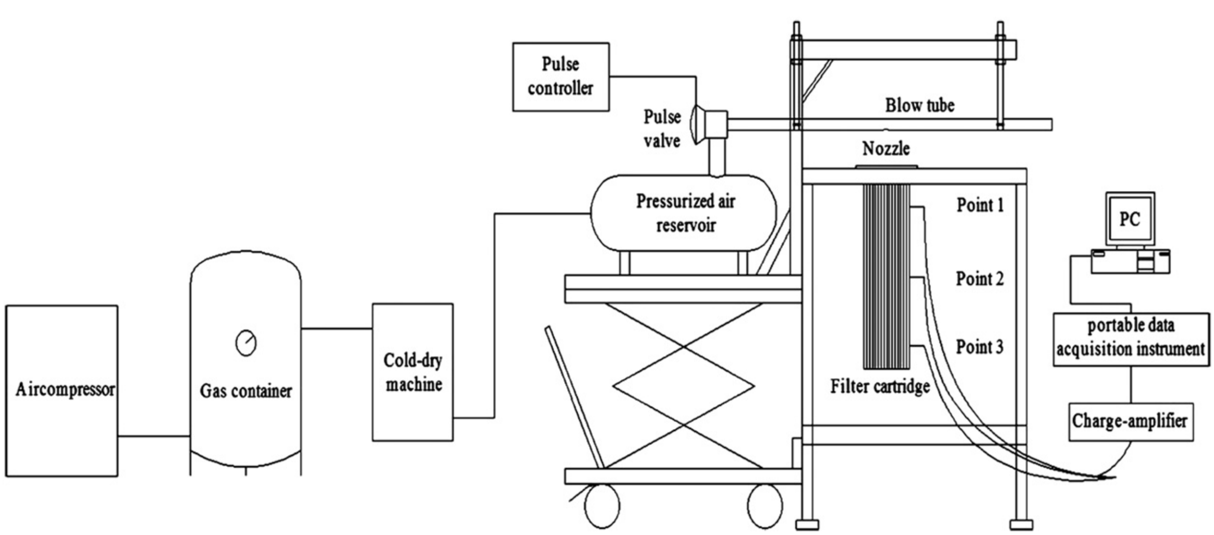

Fig. 1. A schematic diagram of the pulse-jet experimental equipment.