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# Experimental study of the nozzle settings on blow tube in a pulse-jet cartridge filter

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ABSTRACT

In order to improve the cleaning effect of filtration system in a pulse-jet cartridge filter, the nozzle area ratio on a semi industrial pulse-jet cartridge filter was studied, using peak pressure and fabric acceleration as indices. Nozzle area ratio, defined as the total area of nozzles/the cross-sectional area of the blow tube. The experimental results show that the cleaning effect of the filter cartridge firstly increases and then decreases with the increase of nozzle area ratio. The optimum nozzle area ratio is 38.72% in this study. Furthermore, the performance of pulse valve will directly affect the influence of the nozzle area ratio on cleaning effect of a pulse-jet cartridge filter. The study also shows that the optimum nozzle area ratio of a pulse-jet cartridge filter and a pulse-jet bag filter are different, and they are verified by experiment and literature in the study. It suggests that the nozzle area ratio of a pulse-jet cartridge filter cannot be designed in accordance with the parameter of a pulse-jet bag filter.

## 1. Introduction

At present, the environment has continued to worsen with problems related to air pollution, haze pollution and ecological disasters. Findings show that the haze pollution is mainly related to $PM_{2.5}$. That is, the $PM_{2.5}$ is the main pollutant for rigorous control to solve the haze pollution and improve the air quality. In order to choose the right equipment for controlling the ultrafine particles emission, domestic and foreign scholars have done a lot of research work [1,2]. According to Pereira et al. [3], fabric filters are the most important equipment to control the ultrafine particles emission. Therefore, the research and development of fabric filters are vital and essential.

As the development of new materials, new equipments and modern manufacture technologies, great progress has been made in the field of fabric filter in recent years [4]. Compared with common fabric filter, pulse-jet cartridge filter shows a longer service life, a higher efficiency, a smaller volume and more filtration area. Thus, pulse-jet cartridge filter has been widely used to control particulate emissions in such enterprises as petrochemical, chemical, metallurgical, electric power generation, building materials and textiles [3,4].

The pulse-jet cleaning system is the key part among various pulse-jet cartridge filters design [5–7]. Pulse-jet cleaning is an effective and widely used method to clean the filter cartridge. During pulse-jet cleaning, when the compressed air is released, the pulse airflow is delivered through a blow tube to the nozzles. And then into the filter cartridge for increasing the static pressure inside the filter cartridge, which results in the removal of dust cake [8–12]. Yan [13] and Lo et al. [4] have found that the residual dust is unevenly distributed along the surface of the filter cartridge. In particular, the top of the filter cartridge is difficult to clean with pulse-jet cleaning. Many investigators [3,14–20] have studied the methods to improve the cleaning effect of the pulse-jet cartridge filter or bag filter. Lu and Tsai [17,21,22] found that the cleaning effect of the pulse-jet cartridge filter is influenced by many designs and operational parameters, such as blow tube diameter, pulse valve, nozzle diameter, nozzle area ratio (the total area of nozzles/the cross-sectional area of the blow tube) and jet distance. Yan et al. [13] attempted to improve the incomplete cleaning of the filter cartridge by using a supersonic nozzle and an air diffuser.

Qian et al. [18] proposed a mathematical model between jet distance and nozzle diameter. Chio et al. [14] studied the influence of different nozzle shape on cleaning effect of a ceramic filter candle. For filter bag, Jin et al. [23] demonstrated that the nozzle area ratio should be set in the range of 50–65%. Wang et al. [24] verified that the total area of nozzles on the blow tube should be smaller than the cross-sectional area of blow tube, and the nozzle area ratio is 89% in the study. These nozzle area ratios conflicted with the results obtained by Tang et al. [25], who reported that the nozzle area ratio should be 20–30%. According to these reports, at present, there are still some controversies on the nozzle area ratio in actual engineering, and lacking further study on the nozzle area ratio for improving the cleaning effect of the filter

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cartridge. Moreover, filter bag and filter cartridge are composed of different structures and materials. That is, the operational parameters may have different influences on filter bags and filter cartridges. Therefore, it is necessary to systematically investigate the influence of the nozzle area ratio on cleaning effect of a pulse-jet filter cartridge.

In our previous studies, a series of experiments was carried out to discuss the operational parameters of a pulse-jet cartridge filter. The experimental results show that the residual dust cakes are closely related to the peak pressure inside the filter cartridge [26]. Rather, the bigger the peak pressure, the less the residual dust is. That is, the peak pressure is a valid and reliable index for evaluating the dust cleaning effect [18,26]. In addition, the previous study also showed that nozzle diameter has an important influence on cleaning effect of a filter cartridge, and there is an optimum jet distance for each nozzle diameter during pulse-jet cleaning.

The object of this paper is to optimize the nozzle area ratio and study the influence of the nozzle area ratio on cleaning effect of a pulse-jet cartridge filter. In order to achieve the goals, the peak pressure at various total area of nozzles along the filter cartridge, and the variation of peak pressure with time inside the blow tube were investigated on a pulse-jet cartridge filter.

## 2. Experimental setup and design

The experimental setup used for the investigations is shown in Fig. 1. The setup consists of a dust cleaning system, a air supply system and a test data acquisition system. The dimension or the specification of the experimental equipment is shown in Table 1. The compressed air in compressed air tank is provided by a air supply system. When the pulse valve open, the compressed air will be quickly released into the blow tube and then discharged through nozzles into the filter cartridge, which results in high pressure on the surface of the filter cartridge. Three pressure transducers were set downstream of the cartridge to measure the peak pressure. The variation of the peak pressure with time was recorded simultaneously by the test data acquisition system, which was shown in Fig. 2.

In order to understand the relationship between the jet distance and the peak pressure along the length of the filter cartridge, the experimental arrangement of the jet distance is given in Table 2. To investigate the basic principle of the influence of pulse valve on cleaning effect of a pulse-jet filter cartridge at different nozzle area ratios, the variation of peak pressure with time inside the blow tube was tested by pulse valve A and B in this study, respectively. The mechanical properties of two pulse valves are shown in Table 3.

According to the practical industry application, the nozzle diameter, the pulse valve and the number of the filter cartridge are a match for each other. In addition, to avoid the different physicochemical properties of dust and different dust capacities of the filter cartridge, the experiments were carried out without dust in this study.

## 3. Results and discussion

### 3.1. Influence of the jet distance on the peak pressure

The peak pressures on the filter cartridge surface are recorded using three pressure transducers at different nozzle area ratios and jet distances, as shown in Table 4. From Table 4, for all nozzle area ratios and jet distances, the peak pressures increase from the point (1) to the point (2) and then to the point (3), that is, the peak pressures on the filter cartridge surface increase from top to the bottom in pulse-jet cleaning system. During pulse-jet cleaning, the mixture of compressed air and induced airflow move into the filter cartridge. At the top of the filter cartridge, the mixture jet airflow is not fully expanded and dispersed onto the filter surface. Then airflow quickly moves into the bottom of the filter cartridge and rebounds from the bottom. The rebounded airflow then meets the airflow coming from the top of the filter cartridge, resulting in a higher static pressure on the filter cartridge surface[13]. Therefore, the peak pressure on the filter cartridge surface increases from top to the bottom. This result is in good agreement with the study of Lo et al. [1].

From Table 4, it is found that the peak pressure increases first with increasing jet distance and then decreases at any nozzle area ratio. For instance, for a 20.48% nozzle area ratio, the average peak pressure at jet distance of 420, 450, 480, 510 and 540 mm are 1027, 1039, 1062, 1099, and 1088 Pa, respectively. According to the theory of the optimum jet distance evaluation by Qian et al. [18], it is obvious that the highest peak pressure is 1099 Pa, and the optimum jet distance is 510 mm. This fact reveals that there is an optimum jet distance for a set nozzle area ratio. The result is in accordance with Lu and Tsai et al. [4]. That is, the optimum jet distance, for nozzle area ratio of 11.52, 20.48, 38.72, 54.08, 81.92, 115.52 and 154.88% are 540, 510, 480, 360, 300, 240 and 180 mm (the bold font in Table 4) in this study, respectively.

### 3.2. Comparison of different nozzle area ratios on cleaning effect of the filter cartridge

The peak pressures of the filter cartridge at the optimum jet distance for the different nozzle area ratios are shown in Table 5 and Fig. 3. It is evident from Fig. 3 that the average peak pressure was increased first and then decreased with the increase of the nozzle area ratio. This fact indicates that there is an optimum nozzle area ratio on blow tube. From Table 5, it can be seen that the optimum total area of nozzles is 189.97 $mm^2$ and the nozzle area ratio is 38.72% in this study. It is also found that, when the nozzle area ratios are 20.48% and 81.92%, the peak pressure is 499 Pa and 369 Pa at point (1), respectively. Sievert and Loffler [27] demonstrated that the static pressure should reach 400–500 Pa along the length of the cartridge for a good cleaning effect. Thus, the filter cartridge is difficult to clean when the nozzle area ratio is less than 20.48% or more than 81.92%. From the above, these results indicate that the nozzle area ratio is the key influence factor of cleaning performance of the filter cartridge. The reason for this is that the effect of pulse cleaning may vary depending on gas kinetic energy, that is, the airflow velocity at nozzle outlet is the key factor. When to maintain a certain gas volume, the airflow velocity at nozzle outlet depends upon

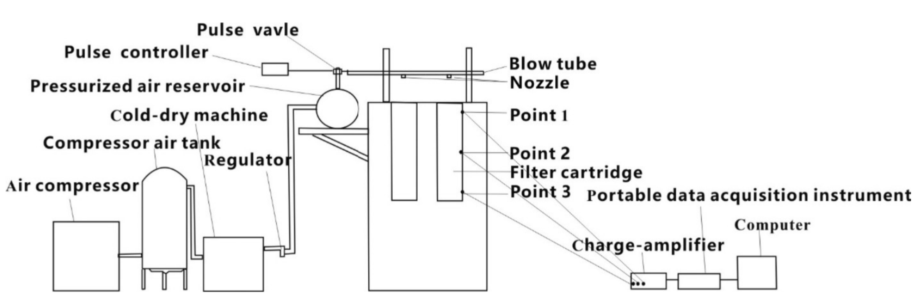


**Fig. 1.** Schematic diagram of the pulse-jet experimental equipment.