Powder Technology 305 (2017) 1–11

Contents lists available at ScienceDirect

Powder Technology

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

Effect of pleat shape on reverse pulsed-jet cleaning of filter cartridges

Shaowen Chen [a], Qiang Wang [b], Da-Ren Chen [b,*]

[a] School of Energy Science and Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China
[b] Particle Lab, Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, 401 West Main Street, Richmond, VA 23294, USA

ARTICLE INFO

Article history:
Received 18 May 2016
Received in revised form 24 August 2016
Accepted 6 September 2016
Available online 8 September 2016

Keywords:
Pleated filter cartridge
Pleat shape
Reverse pulsed-jet cleaning
Reverse pulsed-flow cleaning

ABSTRACT

The effect of pleat shape on the reverse pulsed-jet cleaning of pleated filter cartridges was investigated in this study with the objective of improving the cleaning efficiency and quality. Pleated filter cartridges have been implemented in continuous particle filtration systems equipped with reverse pulsed-jet cleaning technique for filtration unit regeneration. Previous studies have shown that the local sharp variation and non-uniform distribution of static pressure on the surfaces of pleated filter media often result in the decrease in the efficiency and quality of reverse pulsed-jet cleaning as well as the service lifetime of filtration units. In this study a CFD model to calculate the transient flow and pressure fields in a simple filtration system with one filter cartridge during the reverse pulsed-jet cleaning process was developed via ANSYS CFX R.14. The transient static pressure fields for cartridges with four pleat shapes were studied. Significant non-uniformity of static pressure on the high pressure side of filter media for cartridges with typical V-shaped pleats was observed. Significant reduction in the spatial variation of static pressure on the surfaces of pleated filter media for cartridges with other studied pleat shapes was also observed when compared with those for cartridges having V-shaped pleats. A filter cartridge with pleats in the convergent trapezoidal shape was concluded to achieve the maximum and uniformity of static pressure on the filter surfaces and maximal pressure drop across filter media in the reverse flow cleaning. Significant improvement of cleaning efficiency and quality are expected when using filter cartridges with convergent trapezoidal pleats.

1. Introduction

The reverse pulsed-jet cleaning is now a standard technique to regenerate filtration units used in various continuous filtration systems for either powder material recovery or particulate matter removal. Compared with baghouse filters, filtration systems equipped with pleated filter cartridges have the advantages of less pressure drop in the filtration operation, providing an efficient alternative for the particle collection, and less space required for installation [1–2]. For pleated filter cartridges the pleating parameters (such as the pleat pitch, height and count and filter medium thickness) have their individual influence on the filtration performance of a pleated filter cartridge. For reverse pulsed-jet cleaning research has been focused on the improvement of cleaning efficiency and quality for pleated filter cartridges via optimization of operational and pleating parameters [3–5].

Computational fluid dynamics (CFD) tools have been widely applied in understanding the flow and pressure fields in filtration systems under various operation, including the reverse pulsed-jet cleaning [3, 6–16]. One-dimensional (1-D) and two-dimensional (2-D) models have been applied to study the effect of operational parameters on the reversed pulsed-jet cleaning efficiency of baghouse filters and pleated filter cartridges [6–11]. The effects of system parameters, such as injection nozzle diameter, reservoir volume and mass flowrate, on the pulsed-jet cleaning of ceramic filters were studied by a unsteady 1-D and adiabatic flow model [7]. To optimize the filter dimension and system performance 2-D models were further developed to model the transient pulsed-jet cleaning flow behavior for filter bags [8] and ceramic filters [9–11].

Because of increasing computer power and memory, three-dimensional (3-D) modeling of filter cartridges under the reverse pulsed-jet cleaning process now becomes feasible on individual workstations. 3-D numerical modeling of pressure and flow fields around pleated filter cartridges has been performed to evaluate or improve the efficiency of reverse pulsed-jet cleaning [12–13]. Ahmadi and Smith [14] performed a numerical modeling to analyze transient gas flow field and pressure distribution in pulsed-jet cleaning. Lo et al. [3] developed a 3-D model to investigate the cleaning of pleated filter cartridges under the reverse pulsed-jet process. The model was validated by the comparison of average static pressure on the filter surface obtained numerically and experimentally. Li et al. [15] also created a 3-D model to calculate the pressure and flow fields in a ceramic vessel containing three candle filters during the pulsed-jet cleaning. The assessment of turbulence flow models for better predicting the pressure and flow fields in pleated filter systems with rectangular shapes were also reported in the literature [16]. Satisfactory results in analyzing the performance of reverse pulsed-jet

* Corresponding author.
E-mail address: dechen3@vcu.edu (D.-R. Chen).

http://dx.doi.org/10.1016/j.powtec.2016.09.013
0032-5910/© 2016 Published by Elsevier B.V.

cleaning in fabric bags, ceramic filters and pleated filter cartridges were achieved in the aforementioned studies.

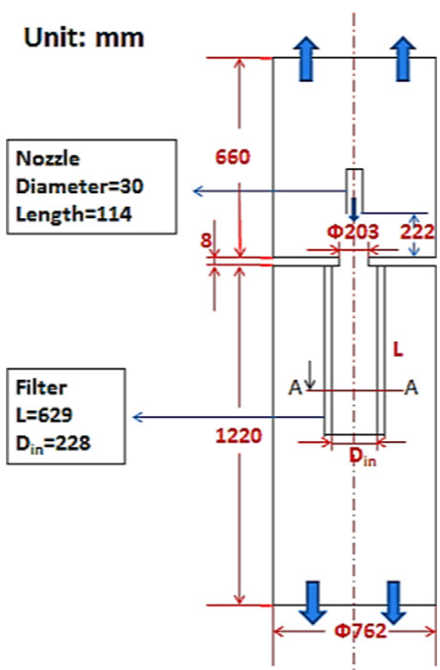
Experimental studies [17–26] were performed to investigate the cleaning performance of the reverse pulsed-jet process. Simon et al. [17–19] had studied the effect of cleaning parameters and operational conditions on the cleaning performance of bag filters. The reverse pulsed-jet cleaning of six pleated filter cartridges (with different base media and geometrical dimensions) were tested in a full-size dust collector, under two cleaning modes, i.e., clean-on-demand and clean-on-time [20], in order to investigate the effect of pleat ratio, filter media and surface treatment on the cleaning efficiency. Previous experimental works [21–24] further identified key parameters in pulsed-jet cleaning systems. These experimental studies provided the valuable reference for the optimization design and technological improvement of reverse pulsed-jet cleaning of pleated filter cartridges.

Filter cartridges with V-shaped pleats were investigated among all the previous studies. The effect of pleat shape on the cleaning efficiency and quality of reverse pulsed-jet process has never been explored in the literature. For a given set of operational parameters applied in reverse pulse-jet cleaning for pleated filter cartridges, it is however hypothesized that more uniform static pressure distribution on filter surfaces and/or pressure difference across the pleated filter media could be obtained via the change of pleat shape. The objective of this study is thus to investigate the effect of pleat shape on the efficiency and quality of reverse pulsed-jet cleaning for pleated filter cartridges. In the following sections we first described the CFD models for investigating the transient flow and pressure fields in a simple filtration system having filter cartridges with four different pleat shapes. The outcome from our numerical investigation is presented in the section of Result and discussion. The summary and conclusion of this study is then given in the last section.

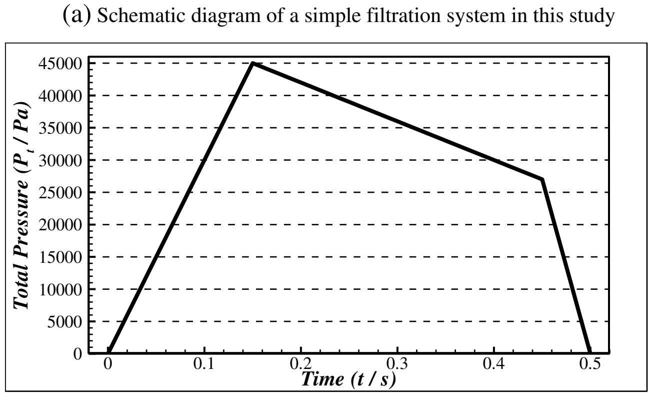
2. Numerical modeling and filter cartridge models

2.1. Studied filtration system

For simplicity a simple filtration system with a single filter cartridge, shown in Fig. 1(a), was selected as the studied system. Basic dimensions of the filtration system under the study are also given in the same figure.

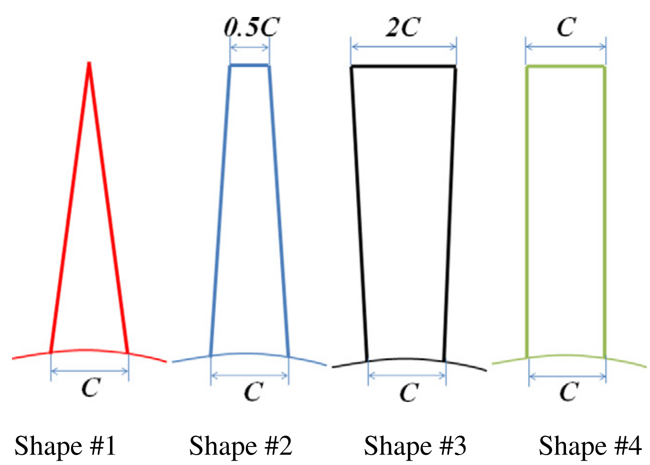


(a) Schematic diagram of a simple filtration system in this study

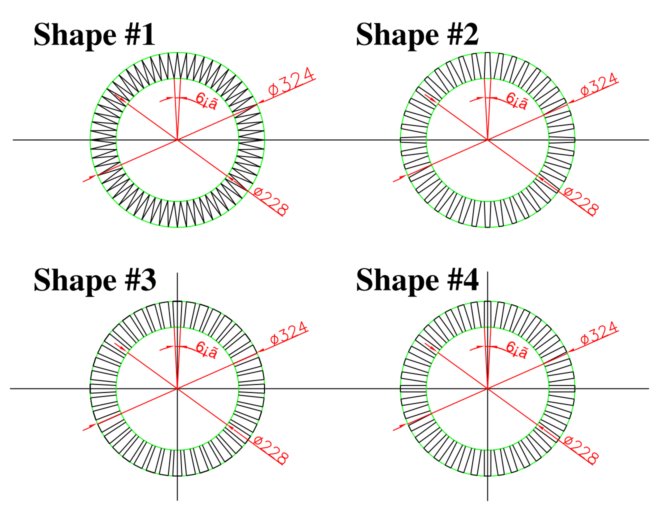


(b) Transient total pressure at the nozzle inlet

Fig. 1. Schematic diagram of a simple filtration system (a) with the assumed total pressure at the nozzle inlet (b).



(a) Studied pleat shapes



(b) Cross-sectional view of filter cartridges with four studied pleat shapes (Diameter Unit: mm)

Fig. 2. Schematic diagram of pleated filter cartridges in this study: (a) four pleat shapes; (b) cross-sectional views of pleated filter cartridges.