Powder Technology 287 (2016) 20–28

Contents lists available at ScienceDirect

Powder Technology

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

Effect of dust loading rate on the loading characteristics of high efficiency filter media

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

[a] Particle laboratory, Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, Richmond, VA 23284, USA
[b] Particle Safety Department, School of Sources and Civil Engineering, Northeastern University, Shenyang, Liaoning, China 110819

ARTICLE INFO

Article history:
Received 30 May 2015
Received in revised form 19 August 2015
Accepted 22 September 2015
Available online 25 September 2015

Keywords:
Dust loading rate
Filter media
Filter pressure drop

ABSTRACT

Experiments were performed to systematically investigate the effect of dust loading rate on the loading curve, i.e., filter pressure drop v.s. loaded particle mass per unit filter area, of high efficiency filter media. Two types of filter media, i.e., glass fiber and electret filters, were selected and loaded with both Arizona road dust and ultrafine dust. Five dust loading rates and two filter face velocities (i.e., 10 and 20 cm/sec) were varied in this study. Our study indicates that the dust loading rate have its non-negligible effect on the loading curve of test filter media, especially at low particle loading rates. It is found that the pressure drop across filter media when loaded with particles at a specific mass per unit filter area decreases as the dust loading rate increases. The effect of loading rate was further evidenced by data analysis on the dust cake pressure drop. An empirical equation was also proposed to describe the loading curves obtained in this study.

1. Introduction

Filtration systems have been used in many industrial sectors such as chemical, nuclear, food, mineral processing industries. Examples of filtration applications include the cleaning of the particulate in exhausts of smelters and coal-fired power plants, the processing of nuclear and hazardous materials, the air purification for semiconductor manufacturing cleanrooms, the respiratory protection and the recovery of powder material. Filter media are the essential component of any filtration systems. The primary parameters to characterize the performance of filter media are the pressure drop and filtration efficiency of filter media. In general, the pressure drop across filter media increases when they are loaded with particles while the particle collection efficiency of loaded filter media improves. The increase of filter pressure drop under the loading condition is attributed to the particle deposition in the media and the dust accumulation on the filter front surface. Understanding the factors affecting the filter pressure drop, eventually being able to estimate the filter pressure drop under the particle loading condition, is of importance in determining the lifetime of filter media being applied.

The particle loading process of fibrous filter media generally precedes through three different phases [2]: after the initial particle collection, the performance of filter media is in the depth filtration regime in which particles are collected inside the media. During the depth filtration regime the filter pressure drop gradually increases as particles continue to be collected. Filter media are then in the so-called transitional regime when a significant percentage of void space in filter media is occupied with particles. The filter pressure drop in transitional regime increases faster as compared to that in the depth filtration. In the last phase of filter media performance, particles are collected on the filter surface (i.e., surface filtration), where the particle cake starts to establish and buildup on the filter surface. The filter pressure drop increases dramatically when they are in the surface filtration regime. For high efficiency filter media, the performance of filter media will stay in the first two phases for only a short period of time and quickly move to the surface filtration regime.

Filtration research has been focused on the investigation of filter media performance under various operational and environmental conditions, such as filtration face velocity, particle types, relative humidity and temperature, and so on [3–7]. However, the effect of particle loading rate on filter loading performance curve had never been systematically investigated in the literature. The only work relevant to the above subject was reported by Saleem and Krammer (2007) [8]. In the above study, the authors considered the factors of face velocity and dust concentration on the formation of dust cake layers in a pilot-scale jet-pulsed bag-house filter system. Three levels of particle mass concentration (i.e., 7.32, 4.81 and 4.53 g/m^3) were tested. They found that the cake density and resistance were higher at lower dust concentration and the filtration velocity had more effect on the filter pressure drop and cake property (i.e., cake density and specific cake resistance) as compared to the dust concentration effect. The tested range of dust concentration was however limited.

In this study experiments were carried out to systematically investigate the effect of particle loading rate on the performance curves of high efficiency filter media under the steady flow operation (at two constant

* Corresponding author at: 401 West Main Street, Richmond, VA 23284-3015.
E-mail address: dchen3@vcu.edu (D.-R. Chen).

http://dx.doi.org/10.1016/j.powtec.2015.09.032
0032-5910/

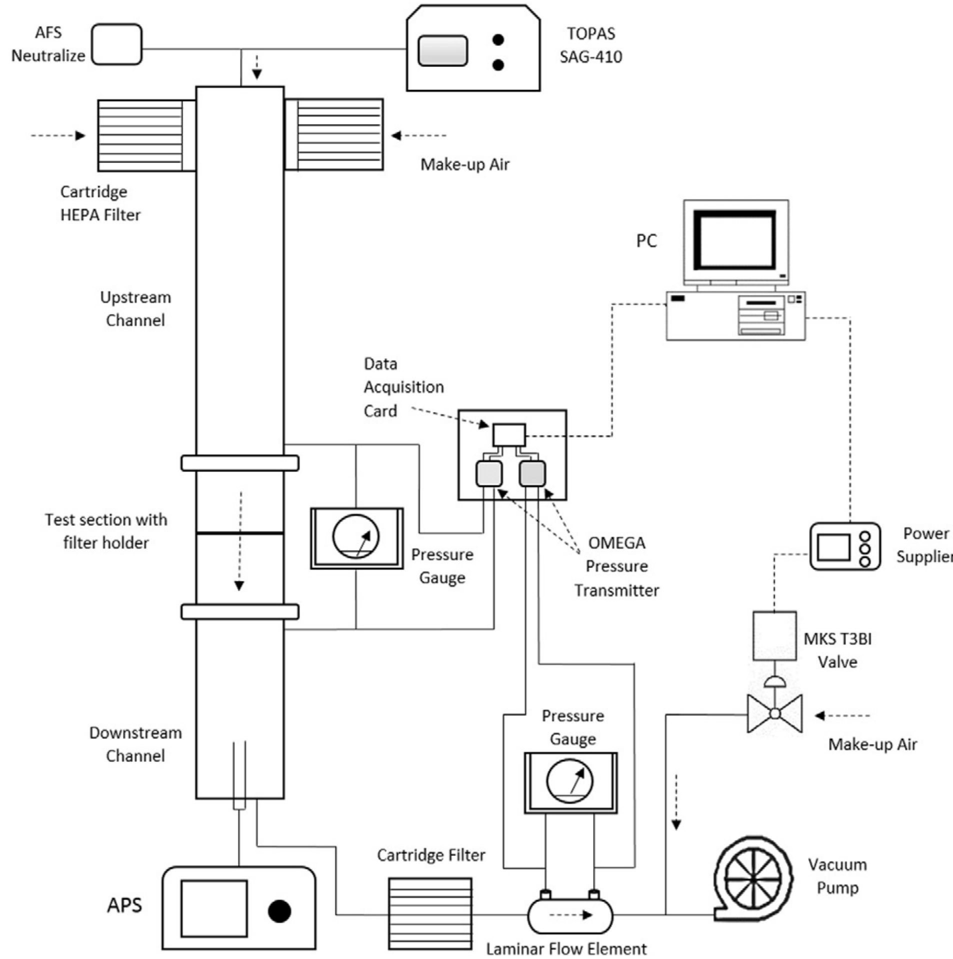

Fig. 1. Schematic diagram of the filter testing setup used in this study.

face velocities of 10 and 20 cm/sec). Two different filter media (glass fiber and electret filter media) were used in this study. Two types of dusts (i.e., ARD and ultrafine dusts) were selected for this test. Based on the collected experimental data a semi-empirical model was further proposed to quantify the effect of particle loading rate on the filter pressure drop.

2. Experimental setup and design

The schematic diagram of our experimental setup for this study is shown in Fig. 1. The setup consists of upper flow channel, test section and lower flow channel. Dry test powders were airborne as test aerosol by a dust disperser (TOPAS SAG-410), and injected into the upper flow channel from the top. Prior to the aerosol injection the electrical charge level of airborne particles was reduced by mixing the stream with bipolar ion flow (from an AC corona discharger with airflow controller AFC; Simco-Ion Industrial Group, Hatfield, PA, USA). Two high efficiency filter cartridges were also included at the setup top to provide clean make-up air flow for filter testing. A custom-made filter holder was located in the test section of the setup. The effective test area of filter media is designed as 100 cm^2. Differential pressure transmitters (OMEGA PX-655) were used to measure the pressure drop across test filter media. All the pressure drop data was recorded by a computer via a data acquisition card (USB-1208FS-Plus, Measurement Computing Corporation, MA, USA). Two ports were included in the upper and lower flow channels to insert probes for particle sampling and measurement. At the downstream of lower flow channel vacuum pumps were used to drive the test flow through the test setup. The total flow rate through the setup was monitored by a laminar flow element, LFE (model Z50MC2-2, Meriam Process Technologies, Cleveland, OH, USA). Two differential pressure gauges (one is OMEGA differential pressure transmitter and the other a mechanical pressure gauge from Dwyer Instruments Inc.) were used to measure the pressure drop of LFE. Because the total flow driven by vacuum pumps was higher than that required for filter testing, a bypass flow channel with a MKS T3BI high speed throttle valve was further included in the test setup to balance the flow. A closed PID control loop was used to adjust the valve opening in order to achieve the desired flow rate through the filter test section.

ISO 12103-1, A3 Medium test dust, known as Arizona road dust (ARD), and *ISO 12103-1*, A1 ultrafine test dust (Powder Technology Inc., Burnsville, MN, USA) were selected as test particles in this study. TOPAS SAG-410 and SAG-410/U were used to disperse ARD and ultrafine

Table 1
Characteristics of tested filter media.

Filter media	Materials	Thickness [mm]	Basic weight [g/m^2]	Permeability [m^2]	Fiber effective diameter [μm][a]	Solidity
A	Borosilicate glass	0.33	93.4	4.14E-13	2.09	0.12
B	Electret	0.40	80.0	2.83E-12	0.28	0.20

[a] Fiber effective diameter was calculated by Kuwabara's cell models.