Development and Filtration Performance Evaluation of Depth Filter Media Cartridge for Gas Turbine Intake Air Filtration

Naim Hasolli[1,2], Ho-Kyung Choi[1], Young-Woo Rhee[2], Young-Ok Park[1*]
[1]Korea Institute of Energy Research, Clean Fossil Energy Research Center,
[2]Chungnam National University, Department of Chemical Engineering
(yopark@kier.re.kr*)

Introduction

Development of the depth filter media includes the process of designing the single layers of the flat sheet filter media, pleat geometry and the assembly of the filter cartridge. In our previous work was stated that depth filter media must have the ability of retaining the particles inside the layer and provide efficient particle collection at low pressure drop for long period of service. Different from the surface filtration the process of particle retention inside the filter mat is more complex [1]. Particles are collected by means of interception, inertial impaction, diffusion, gravitational settling and electrostatic attraction mechanisms [2]. During designing stage, the aim is to achieve the optimum of three main parameters like pressure drop, particle collection efficiency and dust loading capacity. The challenge is to facilitate a media of gradient multiple layer structure. First layer which faces the air stream should serve as pre-filter and should be of more open structure to let the air pass through with less pressure drop and retain the coarse particles. The function of the second layer is to offer sufficient space for dust capture and holding it inside the layer. The target function of the second layer is the dust holding capacity. The final layer should prevent even small particles to pass through and should be of a fibrous structure which would not contribute much to pressure drop increase during the operation period. Fine particle collection efficiency is dependent on this layer. The testing procedure for flat sheet depth filter media is explained in detail in our previous work, see the reference [3]. In this study the main focus is the filtration performance of the filter cartridge assembly, where the filter media, after it has been pleated, is inserted in the cartridge. The cartridge assembly consists of supporting structure and pleated depth filter media. The area of the filter media enclosed in the assembly is related to the initial pressure drop. The target was to achieve a filter cartridge with at least 15 mmAq of the initial pressure drop so that we can relate the filtration performance of the cartridges to this common initial value. Although the filtration area of our test sample cartridges is not equal, the initial pressure drop is almost the same. The aim of this work is to evaluate the performance of the two previously prepared sample cartridges and then based on the results from these tests the following depth filter media should be developed and test with sample cartridge should be conducted.

Experimental set up and method

The characteristics of the depth filter media used for the cartridge assembly are displayed in the Table 1. These data result from the testing procedures which were elaborated in our previous work [3].

Table 1. Test filter media specifications

Specifications/ Filter Media		TFM2	TFM3	TFM5
Layers structure	Layers	3	3	3
Air permeability	$m^3/m^2/min$	15.50	51.51	32.51
Pressure drop@32 L/min	mmAq	2.7	0.88	1.71
Media thickness	mm	1.3	4.2	2.0

The specifications of the test cartridges are displayed in the Table 2. The test filter cartridges have the following dimensions: inner diameter (ID) is 212 mm; outer diameter (OD) is 320 mm and the length (L) of the cartridge is 660 mm.

Table 2. Test cartridge specifications

Specifications/ Test cartridge		TFM2	TFM3	TFM5
Pleat number	Pleats	127	47	150
Pleat height	mm	48	48	48
Effective filtration area	m^2	7.80	2.88	9.21
Filtration velocity	m/min	2.13	5.77	1.80
Terminal pressure drop	mmAq	62		80.2

Tests were conducted under ambient air temperature and humidity conditions. Test dust was the standard ISO A2 Fine (ISO Standard 12103-1). Initial pressure drop (DP) characteristics of the filter cartridge were evaluated by varying the flow rate below and above the value of the nominal flow rate (1000 m^3/min) without injecting the test dust. Dust holding capacity (DHC) test is made by loading the cartridge with dust of high inlet concentration Ci. DHC is expressed in amount of the dust collected during dust loading time which is determined by gravimetric measurements of the cartridge made before and after the test. During the DHC tests, collection efficiency is calculated from the measurements of particle concentration in feed air upstream and downstream of the filter cartridge. Some of these procedures are in compliance with the standard testing procedures of ASHRAE 52.2 and EN779. More detail information can be found in open references [4, 5]. Figure 1 shows the experimental setup with main functional units.

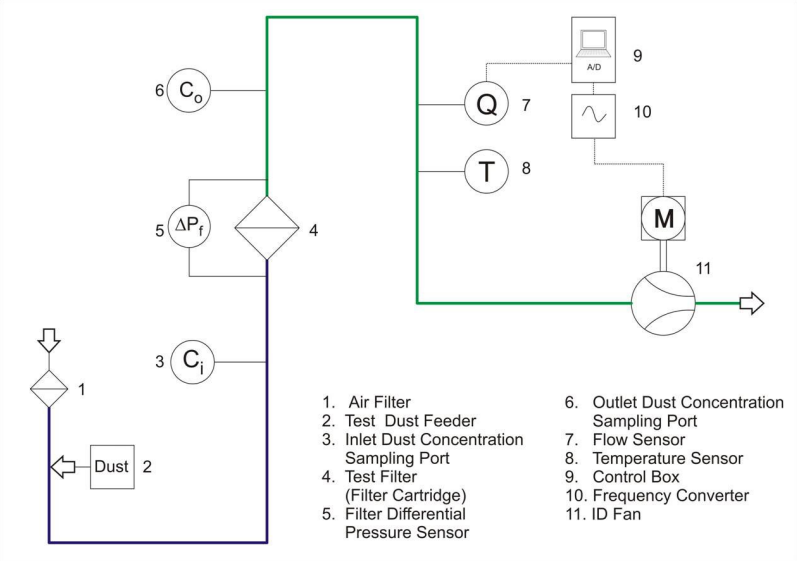

Figure 1. Clean filter pressure drop as function of flow rate

The overall particle collection efficiency E is regarded as the amount of dust retained (Ci - Co) divided by the initial dust concentration Ci expressed in percentage value (Eq.1)

$$E = \frac{Ci - Co}{Ci} \times 100 \qquad \text{(Eq. 1).}$$

The fractional collection efficiency is regarded to concentration of the particles of particular size within the size range 0.54 to 19.81 microns which can be measured by the Aerodynamic Particle Sizer (TSI, model 3321).

Results and discussion

The values for initial pressure drop of all three test cartridges are almost the identical. The cartridge with the media TFM5 has lowest pressure drop through out the range of the flow rate, although the difference is very small compared with other two cartridges, as shown in Figure 2.

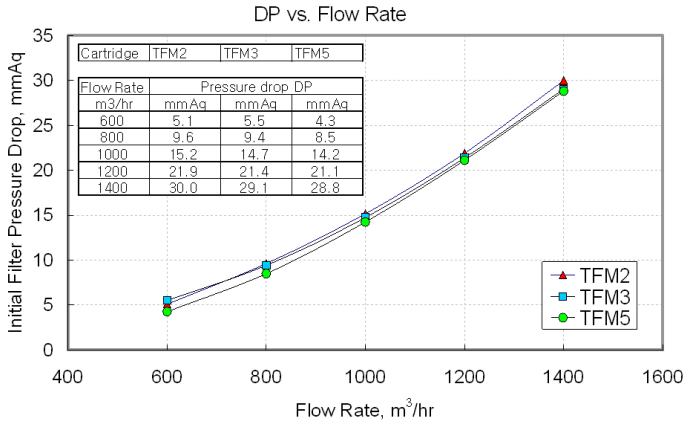

Figure 2. Clean filter pressure drop as function of flow rate

Results from the tests show that the cartridge with TFM5 filter media has the highest dust holding capacity 1774.1g at final pressure drop 80.2 mmAq. The previous TFM2 and TFM3 are tested up to 62 mmAq as the final pressure drop. The DHC value was 482.93 g and 1478.56 g for test cartridges with depth filter media TFM2 and TFM3 respectively.

The test results for the cartridge with TFM5 filter media show that the initial fractional collection efficiency for particles of the range 0.5 to 2 microns is above 99.87%. At final pressure drop 80.2 mmAq the fractional collection efficiency is above 99.98% (Figure 3).

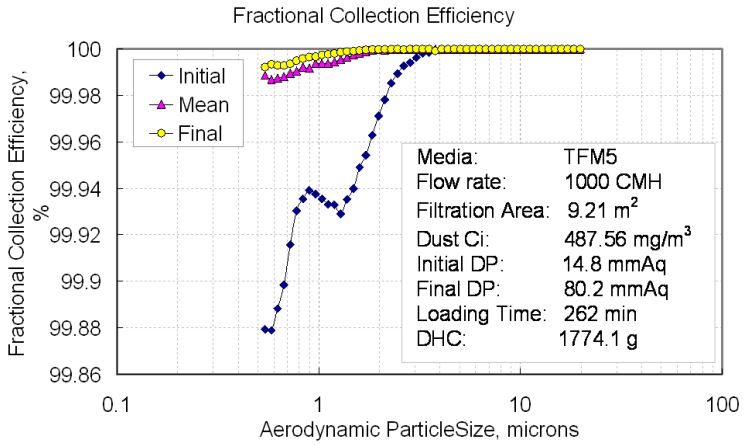

Figure 3. Fractional collection efficiency of depth filter media TFM5

Conclusion

Depth filter media consisting of three layers structure have been developed and filter cartridge assemblies have been made. The shortcomings of the two previous filter cartridges have been remedied. Filter cartridge made of depth filter media TFM5 shows satisfactory filtration performance. The further study needs to be done in order to find an optimum pleat geometry and pleat number with the aim of reducing the initial pressure drop and increase the dust holding capacity.

Reference

[1] Hutten, I. M., *Handbook of Nonwoven Filter Media*, Elsevier, Oxford, 2007.

[2] Hinds, W. C., *Aerosol Technology, Properties, Behavior, and Measurement of Airborne Particles*, 2nd Edn. Wiley, New York, 1982.

[3] Park, Y. O, Hasolli, N., Choi, H. K. and Rhee, Y. W., *Characterization of depth filter media for gas turbine intake air cleaning,* Particle and Aerosol Research, PAAR Vol. 5, No. 4 (2009).

[4] Bitterman, H., *Recent Trends in Air Filter Testing*, www.fiatec.com/fileadmin/user_upload/hammermueller/download/Recent_Trends_in_Air_Filter_Testing.pdf.

[5] NAFA (National Air Filtration Association), *User Guide for ANSI/ASHRAE Standard 52.2-1999*, www.nafaq.org/LibraryFiles/Articles/Article006.htm