INFLUENCE OF LEAKS ON THE FILTER MEDIA PERFORMANCE DURING PULSE-JET FILTRATION

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Abstract: *Outlet emission due to failure of bag filter is challenging problem in many industries. Present study embodies assessment of outlet emission during filtration while leaks appear on filter sample. As it is difficult to study full scale baghouse, flat PTFE coated polyester needle felt filter was tested in the present case. Experimental research has been carried out to observe and understand the emission behaviour of leaks throughout the filtration time. After stabilization of media, the effect of three independent parameters were varied for the study viz. hole diameters (1 mm, 2 mm and 4 mm), positions of hole (top and bottom) and filtration velocities (1.5 m/min, 2 m/min and 2.5 m/min). The behaviour of emitted particles has been studied based on the data generated during online particle measurement system. The experiment leads to the inferences that fresh filter media shows linear increase in emission while leaked media emission rises rapidly. Also effect of larger size of hole on emission is recorded significant compared with smaller size hole.*

Keywords: *Emission, Filtration, Leak, Pulse-jet cleaning.*

1. Introduction

An environmental pollution becomes most challenging subject now a days. Emissions from the coal-fired power plants, municipal waste combustion systems and many other industrial processes have to be filtered to meet the stringent environmental pollution norms. One of the most efficient methods for removing solid particulate contaminants from gas streams is filtration through fabric filter media. This is because the fabric filter is capable of capturing submicron particles as small as 0.5 µm and can also remove a substantial quantity of those particles as small as 0.01 µm. Fabric filters assisted with pulse jet cleaning is popularly used now a days to control the outlet emission and to recover the valuables particles in many industries.

Filter media is used mainly in the form of cylindrical bag under industrial operation. When operated at high temperature, the fabric filter performance can deteriorate due to a variety of causes, such as thermal erosion, mechanical stress through repeated flexing, chemical attack, abrasion etc. During hot gas filtration, a lot of technical intervention is needed for avoiding bag failure. In spite of that pinholes or leaks are common problem in hot gas filtration caused by hot particle. This will lead to increase in outlet dust emission in the atmosphere. Normally large numbers of filter bags are used in industries, so individual online sensor to check the leakage of each filter bags or bag failure are not considered due to the economical aspect. Therefore, some leaked or failed bags remaining undetectable is a huge possibility, these leaked or failed bags can increase the outlet emission level, leading to environmental pollution and directly affects the industrial norms.

It may be noted that previous work done with leakage on filter bag performance is very limited. In one of the previous studies, Theodore and Reynolds were simulated a model equation which predicted the magnitude of the sudden drop in collection efficiency caused by bag rupture (Theodore & Reynolds, 1979). Later Bach and Schmidt were found that bigger pinholes decrease the collection efficiency, whereas higher filter face velocities increase the collection efficiency of filter media (Bach & Schmidt, 2007). Patnaik and Anandjiwala were evaluated the filtration, tensile and bursting strengths and air permeability properties of clean and used filter. The structural changes in all bags (clean, used and chemically treated) were analysed under the Scanning Electron Microscope (SEM). A significant reduction in tensile and bursting strengths after acidic treatment with H_2SO_4 was observed. One of the major reasons for the filter bag failure was attributed to poor acidic resistance of the bags (Patnaik & Anandjiwala, 2015). Kurtz et al suggested, irrespective of the leak position a linear dependency of the clean gas concentration to the leak diameter was found (Kurtz, Meyer, & Kasper, 2015). However, studies regarding the effect of position of varied diameters of holes on the performance of filter media at different filtration velocity have not been reported till date. Present study embodies detailed study of the aforementioned factors on the filtration performance of media filter.

2. Experimental methods

Nonwoven needle felt filter fabric made up of polyester with PTFE membrane coated fabric (Table 1) was used for the experimentation. As it is difficult to execute test in baghouse filter, experiment has been conducted on laboratory set up (Figure 1) using flat base filter media. It may be noted that testing of flat media can provide the behaviour of media performance in full scale baghouse. The test rig consists of the following parts: dust feeder assembly, upstream and downstream chamber, humidity and temperature sensing probe, online dust analyser probe, differential pressure tapings, pulsing nozzle and temporary storage tank, specimen window, specimen frame, damping sheet, pre-filter, HEPA filter, suction arrangement etc. Feeding of dust at predetermined constant rate is accomplished by a dust feeder assembly. The whole set up is divided into two parts by test specimen i.e. upstream and downstream. Two pressure sensors are provided on either side of the test specimen to measure the pressure differential across the media. The emitted dust (not retained by the media) is filtered through pre-filter and HEPA filter. The amount of dust deposited on pre-filter and HEPA filter are useful for gravimetric analysis. The downstream side is connected with on line particle size analyzer 'PROMO 2000' (light-scattering aerosol spectrometer) for detailed analysis of emitted dust particles.

Table 1. Technical specifications of polyester filter fabric

Parameter	Unit	Polyester needle felt fabric
Thickness	mm	2.13
Stiffness	N	73.5
Tensile strength	daN	162
Weight	g/m^2	514
Air Permeability	$Lit/100cm^2/min$	150
Finish type		PTFE coated membrane

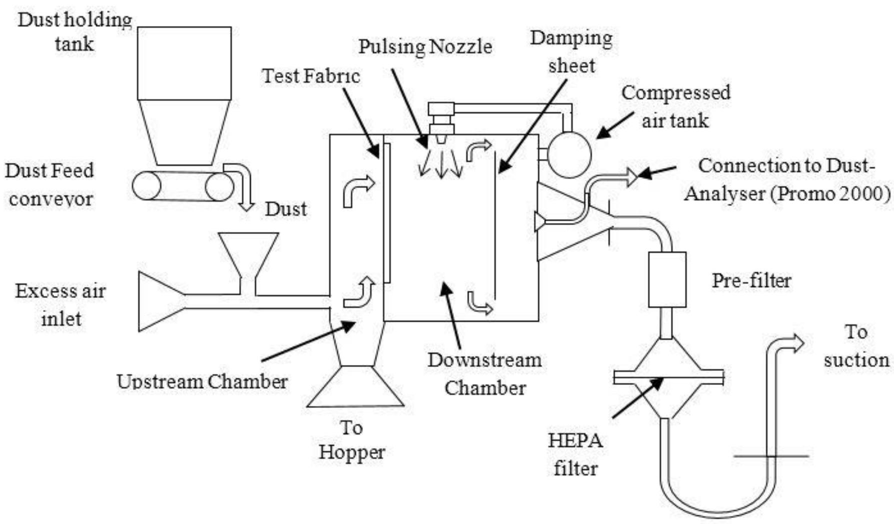
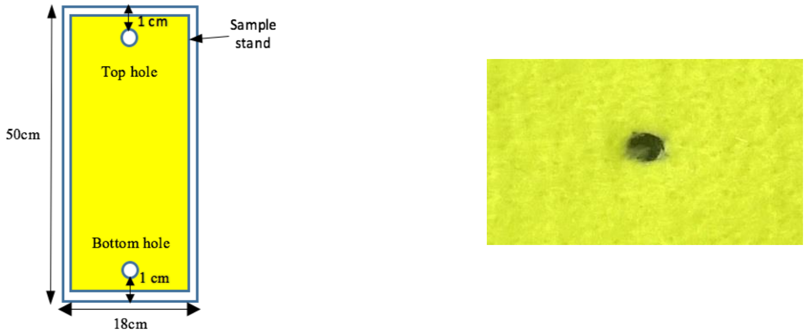


Figure 1. Schematic diagram of Pulse-jet filtration test rig

Filtration test is quite complicated and time taking and the test data are more relevant when the material is stabilized. Therefore, fabric sample (area 900 cm^2) was stabilized according to ASTM 2008 standard using 10000 cycles in conditioning phase and 10 cycles in stabilization phase, afterward final measuring phase carried out for one hour. To study the effect of leakage on emission behaviour, punching of filter media was made after the stabilizing only. The flat media is first removed after stabilization phase and again it is installed after punching. Three different diameters of holes 1 mm, 2 mm and 4 mm were selected on the filter fabric. Holes are made at two different positions (Figure 2) on the filter media by using hole punching machine. Results of measuring phase are mainly incorporated to get the real data of emission and residual differential pressure trend across the media after stabilization phase.



(a) (b)

Figure 2. Sample preparation for testing (a) Position of holes, (b) Hole on filter fabric

The detail working condition considered for the experimental work is as given below:

Test sequences and conditions at stabilizing the media (based on ASTM 2008 standard)

- Conditioning of media (10000 cycles with cleaning pulse at time duration 5 sec), and Stabilizing of media (10 cycles with cleaning pulse at 1000 Pa).
- Filtration velocity of 2 m/min, Dust concentration- 150 g/m³, Pulse jet tank pressure - 200 kPa, Valve opening time- 50 ms.

Test conditions at measuring phase

- Filtration velocity at three level (1.5 m/min, 2 m/min and 2.5 m/min), hole diameter (1 mm, 2 mm and 4 mm), hole position (Top and Bottom), Dust concentration- 150 g/m³.
- Results are based on 1 hour of measuring phase.
- Peak pressure has been defined as the highest pressure drop between 1 hour of measuring phase.

Test dust

- Industrial 'Fly Ash' dust was used to conduct the experiments. Fly ash is fine powder distributed over 0.2-10 µm.

3. Results and discussion

3.1 Effect on particle number concentration between without hole filter and with 1 mm hole filter media

In the present study, the effect of leaks on particle number concentration behaviour of dust across the media has been studied. To compare the results of leaked filter media, filter media (without hole) was tested at same filtration parameters. Direct penetration and seepage of dust particles is very prominent in fresh filter media at time of cleaning pulse (Mukhopadhyay & Dhawan, 2009). After stabilization of media, this phenomenon does not affect much of outlet emission. Results of measuring phase are mainly incorporated to get the real data of particle number concentration across the media after stabilization phase. It is found that with the increase in filtration velocity, number concentration was linearly increased across the filter media. The media without hole shows very less outlet emission of particles than the leaked filter media and also shows very small change in number concentration with the increase in filtration velocity.

From the Figure 3, it is clear that as the hole appears, significant change in number concentration has been found. Continuous increase in particle number concentration can be seen with the increase in filtration velocity for without hole filter media. Whereas, sharp increase in number concentration can be seen for leaked filter media to the filtration velocity increases at higher level.

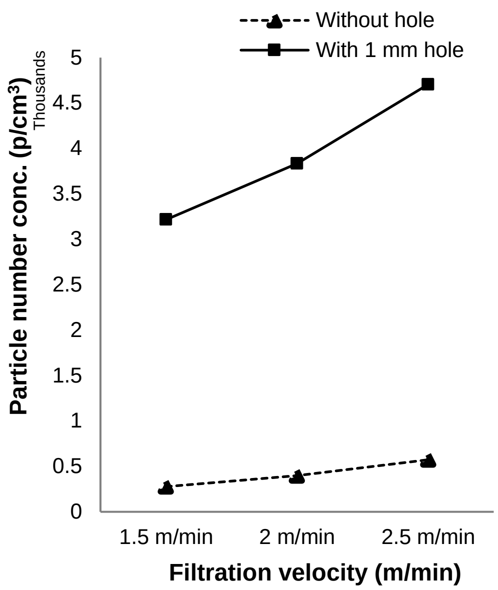


Figure 3. Effect of filtration velocity on particle number concentration between without hole and 1 mm hole filter media

3.2 Effect of various filtration factors on particle number concentration

The effect of leaks on particle number concentration can be seen in Figure 4. With the increase in filtration velocity, ratio of increase in number concentration for smaller hole diameter (up to 1 mm) is very less compared to larger hole diameter (2 mm and 4 mm). Higher number concentration is the result of higher number of finer particles present at the downstream side.

Particle number concentration rises around 4-5 times from 1 mm to 2 mm hole diameter at the top and bottom position of the hole. When hole diameter changes from 2 mm to 4 mm, increase in the ratio of number concentration decreases at the top position around 2 times and bottom position around 3 times. It has also been noted that 4 mm hole at the bottom gives sixteen times higher outlet number concentration when compared to 1 mm hole which is primarily due to increase in hole area by similar extent. From the Figure 4, the impact of bottom position of hole on outlet emission concentration is very prominent for the larger size of hole. Although it is quite small in case of smaller size holes. It can be inferred that bottom position of hole is more vulnerable in the case of larger hole diameter for emission point of view.

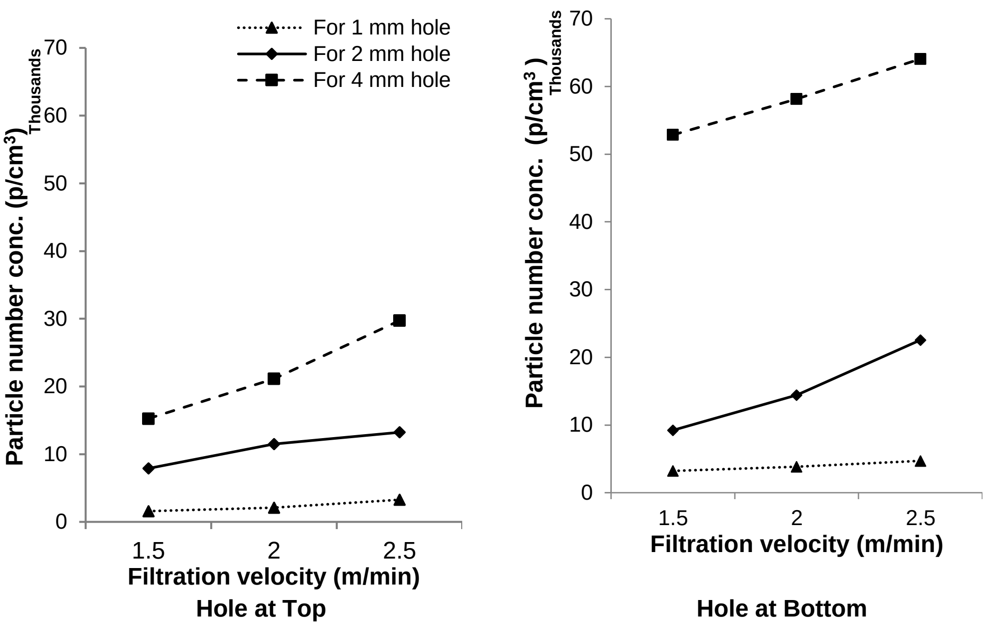


Figure 4. Effect on Particle number concentration at different positions of hole

Table 2 shows ANOVA results based on 0.05 level of significance. Hole diameter shows a major contribution of 62.88%. Whereas, position of hole shows contribution around 13.38%. there is also significant interaction effect between hole diameter and position of holes which shows contribution around 19%. Emission behaves significantly different at top and bottom position with the change in diameter of holes. It can be inferred that larger size holes make a prominent effect at bottom position of hole. Whereas, presence of smaller size hole does not make any significant difference in number concentration at different position of hole. Through ANOVA, it has been observed that impact of filtration velocity is very small on the particle number concentration.

Table 2. ANOVA for particle number concentration

Source	% C
Hole diameter	62.88
Position of hole	13.38
Filtration velocity	2.23
Hole diameter **x** Position of hole	19
Hole diameter **x** Filtration velocity	0.8
Filtration velocity **x** Position of hole	0.01

4. Conclusions

From the present study, regardless the risks of human health and severe limit values for particle emission not only the filtration operation but also phenomena behind the influence of leak filter media during the filtration process was observed and understood. Study infers that particle number concentration mostly depend on hole size rather than filtration velocity. Also, particle emission linearly increased with the filtration velocity.

5. References

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