Prediction of polyester conductive filter media life on flat and pilot filtration test rigs under flyash aerosol pre-charge

Sudev Dutta¹, Arunangshu Mukhopadhyay¹, AK Choudhary¹ and CC Reddy²

Abstract
One of the vital aspects considering the commercial benefit for any gaseous filtration industry is the life cycle of filter material. A filter media providing consistent filtration for a long period of time is desirable for its prolonged life. In view of this; the present study is undertaken for experimental characterization of three different polyester conductive filter materials viz. PTFE coated media, stainless steel fibre blended with PET media, and stainless steel fibre scrim media by predicting their ageing behavior. The materials were investigated on two different laboratory based test rigs viz. flat based and pilot filter unit under two levels of dust densities (50 g/m³ and 150 g/m³) using fly ash aerosol. The aerosol was charged through a pre-charger at three levels viz. 4 kV, 8 kV and 12 kV. The outcome revealed an enhanced ageing performance at higher level of aerosol charge in case of both the test rigs for all the materials. However, the relative performance of the flat media test rig has been found to be better under all operating conditions. The ageing behavior of PTFE coated materials has been found to be the best among all the investigated materials in both test rigs due to its better surface characteristics as a result of coating.

¹Dr B.R. Ambedkar National Institute of Technology, Jalandhar, Punjab, India
²Indian Institute of Technology, Ropar, Punjab, India

Corresponding author:
Sudev Dutta, Textile Technology, Dr B.R. Ambedkar National Institute of Technology, Jalandhar, Punjab 144011, India. Email: Sudev89@gmail.com

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Keywords
Filter media life, ageing indicator, pressure drop, dust charge, dust concentration, conductive filter media

Introduction
During filtration, a filter media is subjected to degradation due to a number of damages such as aerodynamic, mechanical, chemical and thermal, which affects its life. Besides, there are various factors such as the construction of filter media, operating conditions, temperature, humidity etc., on which the life of filter media is dependent. In the case of hot gas filtration, filter media’s life gets affected due to high temperature. While in normal condition, the filter media life is dependent upon the extent of its clogging. In one of the studies the ageing behavior of cleanable filter media at varying filtration velocity and cycle time according to VDI 3926 standard was studied. An extreme increase in pressure drop was reported after a certain ageing time and a cumulative effect of the operating parameters on the increased pressure drop was observed.

In another research, the cleaning mechanism of filter bags supported by rigid rings was analyzed. It was reported that the degree of cleaning is not same along the length of the filter bag, as the acceleration on the filter media at the time of pulsing is higher on the top section and it gradually reduces along its length. Further, the patchy cleaning behavior of filter media at the industrial and laboratory level was compared, where a close agreement in results between them was found. In one of the recent research, the cleaning behavior of pleated filter cartridges by designing a novel colliding pulse-jet cleaning method was studied. A considerable improvement in cleaning performance of filter materials was noticed. During another latest study, the effect of particle size and pressure drop was studied using pleated cartridge filter. It was reported that for the same particle size, both average and average residual pressure drops are reduced with the decrease of maximum pressure, but both the number of pulse-jet cleaning and the average dust emission concentration are increased, which lowers the dust collection efficiency. The track of dust particle is affected by numerous mechanical mechanisms such as inertial impaction, interception, gravitational settling and Brownian motion. These mechanisms deposit the aerosol over the filter media and separate them from the exhaust gas.

It may also be added that some of the previous researches have reported an enhanced filtration performance of filter materials through charging the aerosol particles. In some of the researches, the filtration performance has been studied by using nanofiber techniques. However, its effect on filter media life is yet to be studied at industrial level. Hence, the present study aims to predict the lifetime of filter media investigated on flatbed test rig and pilot filter unit by analyzing the rate of increase in residual pressure drop with the increasing filtration cycle time using flyash aerosol. It may also be added that the flatbed test rig represents the laboratory situation, whereas the pilot filter unit is more close to the industrial situation. Hence, how the material behavior changes going at a scaled up level has been studied through the present investigation. The aerosol particles were charged through negative DC voltage at three
levels viz. 4 kV, 8 kV and 12 kV. The number of pulsing cycles required for the residual pressure drop to reach the pre-defined peak pressure of 1000 Pascal has been calculated by the polynomial equations generated through the pressure drop with time slopes plotted during the measuring phase of the filtration process. Generally, at the industrial scale, filter media is assumed to be at its final stage, after which replacement is necessary. However, in certain industries, the said value is progressively changed to 1500 Pascal for achieving a longer duration of media use at the cost of higher energy.

**Experimental**

**Materials and method**

It is to be noted that usually needle punched nonwoven materials are preferred for the pulse jet filtration industry. It prevents direct penetration of particles through the filter media due to intermeshed pores and sustains the high shock intensity during pulsing operation; nonwoven filters are best suited. Taking into account the aforementioned aspect, the polyester needle punched conductive filter materials have been taken for the present investigation. The material specifications are presented in Table 1. The investigation of materials was carried on two different types of laboratory based pulse jet setups viz. flat media set-up embedded with pre-charger where the filter media is in flat rectangular form as represented in Figure 1 and pilot filter unit where the media is in cylindrical bag shape as shown in Figure 2. It may also be added that, generally the filter materials are tested at laboratory scale in flat form, and at industrial level the shape of filter media is in cylindrical bag form. Hence, for the present case the pilot filter unit is closer to the real time industrial situation. Therefore, the reason for characterizing the ageing performance of filter materials on the two set ups is to analyze how the behavior of the materials changes at a scaled-up level.

| Material type                                      | Fabric mass (g/m²) | Thickness (mm) | Air permeability (m³/m²/min) | Fibre length (mm) | Blend ratio (%) | Punches per cm² |
|---------------------------------------------------|--------------------|----------------|-----------------------------|-------------------|----------------|-----------------|
| Polytetrafluoroethylene coated filter media        | 520                | 2.3            | 8                           | 51                | 100% PET       | 450             |
| Stainless steel fibre blended with polyethylene terephthalate media | 518                | 2.3            | 15                          | 51                | 60% PET with 40% stainless steel fibre | 450             |
| Stainless steel scrim media                        | 505                | 2.1            | 12                          | 51                | 5% of stainless steel fibre in the scrim with 95% of polyethylene terephthalate fibres | 450             |
In flat media rig, the set-up comprised of a dust feeder for uniform dust feeding followed by a pre-charger installed to charge the aerosol particles. A dust layer is created on the surface of filter media during filtration, this dust layer is dislodged time to time on pressure based method at peak pressure level of 1000 Pa through a pulsing time of 50 milliseconds. The downstream side has been attached to an online particle size analyzer ‘Promo 2000’ to analyze the emitted particles. The standard followed was ISO 11057 and the aerosol used was fly ash. The experimental plan followed for both setups has been represented in Table 2. The dimension of flat specimen is 50 cm in length and 18 cm in width.

For pilot filter unit, the mechanism is similar to that of flat media test rig. However, unlike flat media setup, the filter media in this case is in cylindrical bag form. Table 1 represents the specification of materials investigated on both setups. The dimension of each bag has been 125 mm diameter and 800 mm of height.

Testing condition:

- Inlet face velocity: 2 m/min
- Air to cloth ratio: 2
- Inlet dust concentrations: 50 g/m³ and 150 g/m³
- Tank pressure: 2 bar
- Valve opening time: 50 ms
- Total filtration area: 0.09 m² for flat media test rig and 0.65 m² for tubular based set up
- Pulsing at 1000 Pa differential pressure drop

![Figure 1. Experimental set-up of flat media test rig.](image)
Testing sequence:

- Conditioning 30 cycles, cleaning pulse at 1000 Pa.
- Ageing 2500 cycles with a cleaning cycle at 20 s.
- Stabilizing 10 cycles, cleaning pulse at 1000 Pa
- Measuring for 2 h at 1000 Pa (Pressure based cleaning)

The raw dust distribution of fly ash used for filter media characterization is represented in Figure 3.

Figure 4(a) and (b) shows the scatter plot for the residual pressure drop of the present study in the flatbed test rig and pilot plant case, respectively. However, it may be noted that it is challenging to get a steady trend in residual pressure drop in the industry due to variation in dust loading, aerodynamic flow depending upon the media shape and other external conditions such as temperature and humidity.

Based on the residual pressure drop with the increase in filtration time, each material’s trend can be fitted with a second-order polynomial model.
Table 2. Experimental plan followed for both setups.

| Sr.No | Type of filter            | Charge level | Dust inlet concentration level (g/m²) | Replica |
|-------|---------------------------|--------------|---------------------------------------|---------|
| 1     | PTFE coated filter media  | 0 KV, 4 KV,  | 50, 150, 2                           |         |
|       |                           | 8 KV, 12 KV  |                                       |         |
| 2     | S.S fibre blended         | 0 KV, 4 KV,  | 50, 150, 2                           |         |
|       |                           | 8 KV, 12 KV  |                                       |         |
| 3     | S.S scrim filter media    | 0 KV, 4 KV,  | 50, 150, 2                           |         |
|       |                           | 8 KV, 12 KV  |                                       |         |

Figure 3. Raw dust distribution.

\[ y = \beta_0 + \beta_1 x + \beta_2 x^2 \]

Where, \( \beta_0 \) is constant, and \( \beta_1 \) and \( \beta_2 \) are coefficients. ‘x’ is termed as an ageing indicator, the value of x for y to reach 1000 Pascal can be determined once the relationship (i.e. \( \beta_0, \beta_1 \) and \( \beta_2 \)) is known using regression methodology. Higher value of x indicates the greater life of media. Since all the materials taken for investigation were subjected to accelerated testing at a laboratory-based level, the values through the equations indicate to what extent filter media can sustain, and it does not signify their exact life period.
Figure 4. (a, b) Scatter Plot Behavior for Residual Pressure Drop (a) Flatbed Test Rig (b) Pilot Unit.
Results and discussion

The values for ageing indicator ‘x’ and R² for both the test rigs have been represented in Tables 3 and 4 using all the materials for lower and higher dust concentrations respectively. Inferences revealed a high R² along with a significant increase in ageing values for all the materials with a rise in pre-charge level from 0 kV to 12 kV. It may also be added that, in both the test rigs, the role of dust agglomeration due to pre-charging has been vital in increasing the ageing values of the materials, as the contribution of charge has been the highest among all the factors as shown in Table 5.

Besides dust pre-charging, the role of material type and its cumulative behavior with charge has also been prominent. However, the significance of dust has not been considerably less compared to material and charge. As a result of dust agglomeration due to pre-charge, each material’s dust cake properties are improved. Hence the dust particles are prevented from trespassing through the inner layer of the media. This indicates that the movement of dust on the filter media is governed by the media’s pre-charge levels and structure. Thus the role of dust has not been up to the extent of charge and material type.

Impact of charge level and material type on ageing behavior of materials

The ageing indicator behavior of materials with an increase in pre-charge level from 0 kV to 12 kV is represented in Figures 5(a) and (b) and Figure 6(a) and (b) for lower and higher dust densities, respectively. In both the test rigs, relatively high ageing values are observed at lower dust concentration in case of all the materials under charged as well as uncharged condition. This is for the apparent reason of relatively fewer particles in the flue gas at lower dust density, causing reduced loading over the filter surface compared to higher dust density. As a result of the reduced load over the media surface, the particle penetration through the surface will be less; hence prolonged filter life as compared to higher dust density can be expected.

Further, a sharp increase in the test rigs’ ageing values can be noted at initial levels of pre-charge from 0 kV to 4 kV in case of all the materials. While from 4 kV to 12 kV charge, the increase has not been up to a similar extent. The reason for sharp increase in the ageing values from 0 kV to 4 kV charge can be ascribed to the fact of improved dust cake properties in the case of 4 kV charge compared to without charge. Since there are more numbers of smaller particles in the flue gas at uncharged condition, leading to uneven cake formation over the media surface. Also, due to a large number of smaller particles, the chances of particle penetration through the media surface pores become more vulnerable, thereby affecting the life of the filter material. While at 4 kV charge, the particles’ size in the flue gas is relatively large due to agglomeration. This enhances the dust deposition over the media surface resulting in a better cake formation compared to without charge, thereby reducing the depth of particles’ penetration to a significant level. As a result of reduced particle penetration, the material becomes stabilized early as compared to without charge. However, the effect of agglomeration will not be to a similar extent as the pre-charging level increase from 4 kV to 8 kV and further. This is because, for each dust charge level, uniform surface deposition has already been achieved. Therefore,
Table 3. Ageing behavior at 50 g/m³ dust concentration.

| Material type                      | Charge level | Test rig type | Equation                        | R²   | S.E  | Ageing indicator(x) |
|------------------------------------|-------------|---------------|---------------------------------|------|------|---------------------|
| PTFE Coated media                  | 0           | Flat          | \( Y = 415.67 - 0.1302x + 0.0095x^2 \) | 0.89 | 2.91 | 241                 |
|                                    |             | Tubular       | \( Y = 456.94 - 0.0169x + 0.0095x^2 \) | 0.83 | 4.06 | 180                 |
|                                    | 4           | Flat          | \( Y = 382.42 - 5.7051x + 0.0127x^2 \) | 0.93 | 2.14 | 539                 |
|                                    |             | Tubular       | \( Y = 482.93 - 74139x + 0.0295x^2 \) | 0.91 | 3.96 | 397                 |
|                                    | 8           | Flat          | \( Y = 420.2 - 11.1845x + 0.0209x^2 \) | 0.95 | 2.94 | 582                 |
|                                    |             | Tubular       | \( Y = 415.62 - 2.4015x + 0.008x^2 \) | 0.94 | 3.74 | 459                 |
|                                    | 12          | Flat          | \( Y = 210.53 - 7.1927x + 0.0143x^2 \) | 0.90 | 2.03 | 595                 |
|                                    |             | Tubular       | \( Y = 420.81 - 4.6651x + 0.0124x^2 \) | 0.93 | 2.86 | 474                 |
| S.S Fibre blended with PET media   | 0           | Flat          | \( Y = 415.43 + 2.8602x + 0.0035x^2 \) | 0.81 | 4.12 | 190                 |
|                                    |             | Tubular       | \( Y = 539.74 + 1.0098x + 0.0147x^2 \) | 0.87 | 5.56 | 145                 |
|                                    | 4           | Flat          | \( Y = 396.6 - 1.7745x + 0.0097x^2 \) | 0.89 | 3.89 | 357                 |
|                                    |             | Tubular       | \( Y = 474.18 + 0.7355x + 0.0033x^2 \) | 0.92 | 3.07 | 302                 |
|                                    | 8           | Flat          | \( Y = 291.55 - 2.2571x + 0.103x^2 \) | 0.86 | 2.13 | 393                 |
|                                    |             | Tubular       | \( Y = 437.52 - 2.6843x + 0.0124x^2 \) | 0.83 | 3.41 | 347                 |
|                                    | 12          | Flat          | \( Y = 464.11 - 6.7254 + 0.0202x^2 \) | 0.90 | 2.43 | 399                 |
|                                    |             | Tubular       | \( Y = 444.47 - 3.6633x + 0.0139x^2 \) | 0.86 | 2.72 | 371                 |

(continued)
in the case of 8 kV and 12 kV charge, cake deposition enhancement will be marginally better than 4 kV charge. Hence the extent of improvement will not be similar to 0 kV and 4 kV charge.

Further, the relative assessments of materials revealed the highest ageing values for PTFE coated media followed by stainless steel fibre blended with PET media and stainless steel fibre scrim media in both the test rigs. It may also be added that the level of increase in ageing values at the initial level of pre-charge from 0 kV to 4 kV is also noted to be the highest for the PTFE coated material in case of both test rigs and dust densities. This can be ascribed due to the benefit of coating over the surface of PTFE coated material, resulting in a higher level of the reduction in the depth of penetration as the pre-charge level increases from 0 kV to 4 kV in case of the PTFE coated material. The coating over the PTFE coated media is non-sticky, the primary cake layer formation over its surface will be relatively less. Apparently, the subsequent secondary layer deposition will take a relatively long time. Therefore, the pulsing interval will be higher than the other two materials that do not benefit from coating; hence, the PTFE material is expected to get stabilized relatively early and provide consistent filtration for a longer time, leading to prolonged life of the filter material. However, in the case of stainless steel fibre blended with PET media and stainless steel fibre scrim media, as the benefit of coating is not there, the level of reduction in depth of penetration is less than PTFE coated media. Therefore, the smoothness of dust dislodgement during pulsing is not similar to the coated material. Hence the pulsing interval is reduced, and the materials are expected to clog relatively early. It can also be inferred that the difference between the slopes of PTFE coated material and the other two materials has been much higher in both the test rigs. This

Table 3. (continued)

| Material type                  | Charge level | Test rig type | Equation                                      | \(R^2\) | S.E | Ageing indicator(x) |
|-------------------------------|--------------|---------------|-----------------------------------------------|--------|-----|---------------------|
| S.S Fibre Scrim Media         | 0            | Flat          | \(Y = 405.23 + 0.6901 + 0.0137x^2\)           | 0.81   | 2.81 | 184                 |
|                               |              | Tubular       | \(Y = 522.72 + 2.4572x + 0.0084x^2\)         | 0.89   | 3.46 | 133                 |
|                               | 4            | Flat          | \(Y = 502.97 - 3.0545x + 0.0166x^2\)         | 0.87   | 4.76 | 287                 |
|                               |              | Tubular       | \(Y = 564.18 - 4.2743x + 0.227x^2\)         | 0.81   | 4.37 | 261                 |
|                               | 8            | Flat          | \(Y = 402.57 + 1.2362x - 0.0012x^2\)         | 0.86   | 3.04 | 318                 |
|                               |              | Tubular       | \(Y = 466.02 + 1.4631x + 0.0012x^2\)         | 0.82   | 2.81 | 294                 |
|                               | 12           | Flat          | \(Y = 393.36 + 1.2081x + 0.0015x^2\)         | 0.88   | 4.98 | 350                 |
|                               |              | Tubular       | \(Y = 439.15 + 0.7379x + 439.15x^2\)        | 0.85   | 4.39 | 399                 |
Table 4. Ageing behavior at 150 g/m³ dust concentration.

| Material type       | Charge level | Test rig type | Equation                                      | $R^2$ | S.E  | Ageing indicator(x) |
|---------------------|--------------|---------------|-----------------------------------------------|-------|------|---------------------|
| PTFE Coated media   | 0            | Flat          | $Y = 461.16 - 0.4688x + 0.0095x^2$             | 0.84  | 4.87 | 174                 |
|                     |              | Tubular       | $Y = 576.94 - 2.5102x + 0.0075x^2$            | 0.81  | 5.29 | 123                 |
|                     | 4            | Flat          | $Y = 443.28 + 1.0681x + 0.004x^2$             | 0.91  | 3.31 | 262                 |
|                     |              | Tubular       | $Y = 487.14 - 2.1276x + 0.0023x^2$           | 0.89  | 4.82 | 202                 |
|                     | 8            | Flat          | $Y = 440.7 - 1.0697x + 0.0096x^2$            | 0.90  | 3.47 | 303                 |
|                     |              | Tubular       | $Y = 410.61 - 1.1910x + 0.0166x^2$          | 0.88  | 4.51 | 227                 |
|                     | 120          | Flat          | $Y = 412.52 - 2.2590x + 0.0128x^2$          | 0.89  | 3.95 | 319                 |
|                     |              | Tubular       | $Y = 464.22 - 1.0967x + 0.0139x^2$          | 0.92  | 5.27 | 239                 |
| S.S Fibre blended   | 0            | Flat          | $Y = 621.46 + 3.3244x + 0.0015x^2$          | 0.79  | 5.94 | 108                 |
| with PET media      |              | Tubular       | $Y = 520.76 + 4.8415x + 0.0212x^2$          | 0.74  | 6.97 | 74                  |
|                     | 4            | Flat          | $Y = 537.76 + 0.8012x + 0.0248x^2$          | 0.86  | 4.39 | 193                 |
|                     |              | Tubular       | $Y = 512.08 + 0.098x + 0.0248x^2$          | 0.81  | 4.93 | 138                 |
|                     | 8            | Flat          | $Y = 489.61 - 0.04681x + 0.0248x^2$         | 0.87  | 3.08 | 224                 |
|                     |              | Tubular       | $Y = 458.01 + 0.6585 + 0.0164x^2$         | 0.80  | 3.94 | 162                 |
|                     | 12           | Flat          | $Y = 462.97 - 1.1789x + 0.0141x^2$         | 0.87  | 3.64 | 241                 |
|                     |              | Tubular       | $Y = 377.63 + 0.0305x + 0.0197x^2$         | 0.86  | 4.18 | 176                 |

(continued)
indicates that the lifetime of the filter material can be significantly enhanced through the surface coating.

Further observations revealed that the relative behaviour between test rigs for the ageing values has been different, as the said values are higher for the flat media test rig. The comparative analysis of the test rigs has been detailed in the next section.

The materials were subjected to half decay time test i.e. the time taken for the surface charge of the materials to reach half of its potential was observed as represented in Table 6. It has been analyzed that the material taking a long time to dissipate charge is exhibiting higher ageing values. This is because as the charged particles get deposited over the media’s surface, during charge dissipation, the agglomerated particles break and loosen up. More dissipation time suggests that agglomerated particles loosen slowly, which delays the particles to trespass into the inner layer, and the particles remain on the surface of media for a relatively more extended period resulting in lower depth of penetration. Therefore, the particulate emission reduces, as a result the ageing values are higher. Further, from Figure 7(a) to (d) the particle depth of penetration is noted to be highest for without charge and reduces with subsequent increase in pre-charge level in all materials under both dust density.

**Correlation between the test rigs**

The inferences revealed significantly higher ageing values for the flat media test rig than the pilot filter unit in the case of all three materials. As due to the longer height of pilot filter media, the aerodynamic flow across the said media will be relatively unsteady.
Table 5. Percentage contribution and F values for ageing indicator derived from three-way ANOVA.

| Material | Dust concentration | Material x charge | Charge x dust & concentration | Dust concentration x material |
|----------|-------------------|-------------------|-----------------------------|-----------------------------|
| Flat     | Flat              | Flat              | Flat                        | Flat                        |
| Pilot    | Pilot             | Flat              | Pilot                       | Flat                        |

- Contribution (%): 20.14, 21.43, 21.08, 26.33, 21.27, 15.31, 23.33, 17.14, 7.29, 11.54, 14.67, 7.16
- F Value: 56.72, 70.09, 82.52, 91.31, 27.01, 35.04, 42.07, 37.17, 21.84, 28.27, 33.16, 18.67

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Figure 5. (a, b) Ageing indicator behavior at 50 g/m$^3$ dust concentration (a) Flat media test rig (b) Pilot filter unit.
Figure 6. (a, b) Ageing indicator behavior at 150 g/m³ dust concentration (a) Flat media test rig (b) Pilot filter unit.
Hence, the dust deposition over its surface is relatively non-uniform. Also, the possibility of dust dislodgement due to gravity is higher in the case of pilot media, and the degree of cleaning during pulsing is not same along the length of said unit, thereby resulting in patchy cleaning. Therefore, it can be inferred that the combined effect of the aforementioned facts is responsible for the pilot filter media to clog relatively early, thereby resulting in higher residual pressure drop and emission, thus affecting the life of the pilot filter media. Further observations revealed a major contribution of charge in both the test rigs as represented in Table 7. However, the charge’s role is marginally higher in the case of the pilot filter unit, and the interaction behavior of dust and charge is also more for the said unit. This can be attributed to the combined effect of higher amount of current applied to charge the dust particles in the case of the pilot plant, and more absolute number of particles larger than the size of 1 μm in the flue gas for the said unit. It can also be inferred from Table 3 that the smaller height of the flat media test rig has been responsible in providing more significant interaction behavior of the material with dust and charge as compared to that of the pilot filter unit. As due to smaller height, the dust deposition over the flat media surface is relatively uniform, thereby providing an improved cumulative effect with the flat media surface as compared to that of the pilot media.

Further inferences revealed that for PTFE coated material, dust charges play a major role in improving its life cycle among all the investigated materials, as represented in Table 8. This can be attributed to better surface filtration due to PTFE coating on the media, leading to uniform cake formation, resulting in smooth dislodgement of dust, which is evident from the depth of penetration results which is noted to be the least for PTFE coated media at all pre-charging and without charge levels as represented in Table 9. While the surface of stainless steel fibre blended with PET media and stainless steel fibre scrim media are non-coated, the benefit of charge on these materials is not similar to the coated material. The fractional penetration values for varying dust charge level has been represented in Table 10. To assess the reduction in depth of dust penetration inside the filter media at varying pre-charge levels, the cross-sectional images of tested filter media were captured through binary image procedure. The segment $A_1$ in the Figure 8 represents the area covered by the dust, whereas $A_2$ denotes the portion of without dust. The average thickness of dust penetration, filter media (without dust) and fractional penetration of dust can be expressed through the equations (1)–(3) respectively. Where $L$ is the length of specimen under study.

It may also be added that 15 such experiments specific to fractional penetration of dust were conducted at varying pre-charge levels.

### Table 6. Charge dissipation behavior of investigated materials.

| Type of media                               | 4KV | 8KV | 12KV |
|--------------------------------------------|-----|-----|------|
| PTFE coated media                          | 9.2 | 11.4| 12.8 |
| Stainless steel fibre blended with PET Media | 6.8 | 8.1 | 10.9 |
| Stainless steel fibre scrim media           | 4.9 | 7.2 | 9.2  |
Table 7. Percentage contributions for ageing indicator for both dust concentrations derived from two-way ANOVA.

| Factors                  | Lower dust concentration | Higher dust concentration |
|--------------------------|--------------------------|---------------------------|
|                          | Flat media test rig      | Pilot filter unit         | Flat media test rig | Pilot filter unit |
| Material                 | 32.11                    | 35.17                     | 36.30               | 33.42             |
| Charge                   | 35.71                    | 39.43                     | 39.17               | 44.07             |
| Material x Charge        | 29.83                    | 22.28                     | 21.52               | 17.41             |

Table 8. Percentage contributions for ageing indicator for each material derived from two-way ANOVA.

| Factor                        | PTFE coated media | Stainless steel fibre blended with PET media | Stainless steel fibre scrim media |
|-------------------------------|-------------------|---------------------------------------------|----------------------------------|
|                               | Flat based test rig | Pilot filter unit | Flat based test rig | Pilot filter unit | Flat based test rig | Pilot filter unit |
| Dust Concentration            | 35.31             | 35.86                        | 34.48                           | 33.18             |
| Charge                        | 42.19             | 36.94                        | 35.96                           | 38.30             |
| Charge x Dust Concentration   | 19.27             | 22.81                        | 23.89                           | 25.21             |

Figure 7. (a, b, c, d) Depth of aerosol penetration (a) 0 kV (b) 4 kV (c) 8 kV (d) 12 kV.
Table 9. Depth of penetration at all charge levels and without charge.

| Filter media type                                      | Depth of penetration at 0 kV charge (mm) | Depth of penetration at 4 kV charge (mm) | Depth of penetration at 8 kV charge (mm) | Depth of penetration at 12 kV charge (mm) |
|-------------------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| Dust density 50 g/m$^3$ 150 g/m$^3$                   | 50 g/m$^3$ 150 g/m$^3$                   | 50 g/m$^3$ 150 g/m$^3$                   | 50 g/m$^3$ 150 g/m$^3$                   | 50 g/m$^3$ 150 g/m$^3$                   |
| PTFE Coated media                                     | 1.88 1.91                                | 0.71 0.88                                | 0.59 0.74                                | 0.43 0.62                                |
| Stainless steel fibre blended with PET media           | 1.95 2.03                                | 0.89 1.01                                | 0.70 0.78                                | 0.49 0.64                                |
| Stainless steel fibre scrim media                     | 1.97 2.06                                | 1.02 1.11                                | 0.92 1.01                                | 0.64 0.82                                |
Table 10. Fractional penetration of dust at varying charge levels.

| Material type                                           | 4 KV charge | 8 KV charge | 12 KV charge |
|---------------------------------------------------------|-------------|-------------|--------------|
| PTFE coated media                                       | 0.38        | 0.24        | 0.20         |
| Stainless steel fibre blended with PET media            | 0.57        | 0.48        | 0.41         |
| Stainless steel fibre scrim media                       | 0.62        | 0.53        | 0.47         |

Figure 8. Cross-sectional image of tested filter media.

Figure 9. Correlation of ageing indicator between flat and pilot test rigs.
Average thickness of dust penetration \[ \frac{A_1}{L} \] (1)

Average thickness of filter media (without dust) \[ \frac{A_2}{L} \] (2)

Fractional penetration of dust \[ \frac{A_1}{A_1 + A_2} \] (3)

From Figure 9 a strong correlation of 0.94 can be observed between the test rigs.

**Conclusions**

Prediction for the ageing behavior of different conductive materials on both the test rigs revealed that the filter media can provide a consistent filtration for a relatively longer period of time using flat media test rig. This can be attributed to the relatively small height of the flat media responsible for providing more consistent filtration than the pilot filter unit. In both the test rigs, the ageing values are observed to increase for all the materials with rise in pre-charging level from 0 kV to 12 kV. Further inferences revealed that the level of increase in the ageing values from 0 kV to 4 kV charge has been much higher than 4 kV–8 kV charge and further. It may also be added that the coating over PTFE coated media has been beneficial for its highest ageing values among all the investigated materials. In view of this, it can be predicted that through surface coating, the life of filter media can be enhanced significantly. Higher amount of current applied to charge the flue gas particles in the pilot filter unit and more number of absolute particles of size greater than 1 μm for the said setup have been responsible for its more significant interaction of dust with charge than that of flat filter unit. However, the interaction of the material with charge and material with dust has been better in the case of flat media test rig, this can be ascribed due to uniform deposition of the dust particles over the flat media surface.

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**ORCID iD**

Sudev Dutta [https://orcid.org/0000-0003-4212-1129](https://orcid.org/0000-0003-4212-1129)
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