CHEMICAL ENGINEERING TRANSACTIONS

VOL. 72, 2019

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Jeng Shiun Lim, Azizul Azri Mustaffa, Nur Nabila Abdul Hamid, Jiří Jaromír Klemeš

**ISBN** 978-88-95608-69-3; **ISSN** 2283-9216

DOI: 10.3303/CET1972007

# Effect of Filter Aids on Two Different Filter Media Under High Filtering Velocities

Nurnadia Andenan[a,]*, Mohd Rashid[a], Siti Hajar[a], Nor Ruwaida Jamian[a], Khairunnisa Mohd Pa'ad[a], Ammar Mohd Rashid[b]

[a]Malaysia-Japan International Institute of Technology, UTM Kuala Lumpur, Malaysia
[b]AMR Environmental Sdn Bhd, Johor Bahru, Malaysia
nurnadiaandenan@gmail.com

A fabric filter is an excellent air pollution control device for fine particles emissions control due to its high collection efficiency. The problem associated with fabric filter is that it has a short life span due to wear and tear connected with the operating conditions of the system. Treatment of fabric filter using filter aids is one of the simplest techniques to overcome this problem. In this study, the effect of filtration aids known as PrekotAC, onto two different types of filter media i.e PTFE and ryton under high filtering velocity was carried out in a laboratory scale filtration system. This formulated filter aids PrekotAC material which consists of activated carbon and PreKot™, served as a two in one filter aids material (adsorbent and pre-coating material) that helps to overcome the wear and tear problem as well as control the emission of sub-micron pollutants in air pollution control. The effect of the various combinations of filtration aids on pressure drop, particle penetration and permeability across the two-filter media under different filtration velocities was investigated. Results showed that ryton presents a lower pressure drop under various combinations of PrekotAC for different filtration velocities compared to PTFE. A lower pressure drop across the fabric filter resulted a higher permeability property of ryton which allows higher volumetric air flow rates passing through it compared to PTFE filter. The study suggests that the addition of PreKotTM in the formulation of PrekotAC significantly affect both pressure drop and permeability of the filter media. The study also showed that the total particle penetration through the filter media is highly influenced by the filtration velocity. It was found that the total particle penetration through PrekotAC 10 : 90 (wt% basis of PreKotTM:activated carbon) was the lowest while the highest was PrekotAC 40 : 60 of the four formulated PrekotAC admixtures. In addition, the total particles penetrating through the filter media was the highest for the highest filtering velocity of 8 m/min for all cases.

## 1. Introduction

Human activities are one of the main sources of air pollution which includes emissions from industries and burn-up of the fossil fuels (Desiree et al., 2018). Fabric filters are increasingly popular as an air pollution control system for the removal particle from gas streams but are sensitive to high temperatures and humidity. This air pollution control system has efficiently removed the particulates produce from the incineration process (Margallo et al., 2012). It has excellent collection efficiency of 99.9+ % for the removal or separation of coarse particles as well as fine particles through filtration process in many industrial applications. Flue gas cleaning agents such as activated carbon and lime are normally used along with fabric filter for air emission control especially in waste incineration processes. The life span of the fabric filter is usually shortened and influenced by the variations of the flue gas as well as the operating conditions of the process. The filtration performance of the fabric material deteriorated with time and simultaneously increasing the maintenance cost having to replace it within a short period of time.

A simple technique is to apply so called 'pre-coat' agent or filtration aids to coat a layer of inert material onto the each of the fabric as a barrier for protection as well as to allow a uniform air flow passing through the filter media. PrekotAC consisting combination of a precoating material (i.e PreKotTM) and activated carbon. In this study, ryton and PTFE are examples of the conventional needle felt filter media that used in fabric filter unit to evaluate

Paper Received: 04 April 2018; Revised: 05 August 2018; Accepted: 28 September 2018

Please cite this article as: Andenan N., Rashid M., Hajar S., Jamian N.R., Mohd Pa'ad K., Mohd Rashid A., 2019, Effect of filter aids on two different filter media under high filtering velocities, Chemical Engineering Transactions, 72, 37-42 DOI:10.3303/CET1972007

the performance. The effect of the PrekotAC filtration aids based on various combination of PreKot™ and activated carbon on pressure drop, particle penetration and permeability across PTFE and ryton filter media under different filtration velocity was investigated.

## 2. Materials and methods

### 2.1 Activated carbon and PreKot™

A powder form coconut shell based activated carbon and PreKot™ was used in this study. Table 1 summarised the specifications of the material used in the formulation. PrekotAC was formulated by mixing the adsorbent activated carbon with the pre-coating material PreKot™. The formulation was prepared in four different proportion of PreKot™ from 10 % to 40 % by weight. Both activated carbon and PreKot™ were dried in an oven at 105 °C for 24 hours before mixing.

*Table 1: Specifications of activated carbon and PreKot™ used in the formulation*

| Activated carbon | PreKot™ |
|---|---|
| Form and colour: powder, black | Form and colour: powder, snowy white |
| Origin: coconut shell based | |
| pH: 9 - 11 | Fusion point: 1,300 - 1,400 °C |
| Ash content: 8 % max | Softening point: 900 - 1,100 °C |
| Surface area: 850 m²/g | Thermal conductivity: Less than 0.058 W/mK at 0 °C |
| Bulk density: 440 kg/m³ | Bulk density: 119 kg/m³ |

Note: PreKot™ is a proprietary of AMR Environmental Sdn. Bhd

### 2.2 The filtration test system

Figure 1 presents the experimental setup for the filtration system designed in this study, which consists of a dust feeder, filter media, pressure manometer, particle counter, rotameter, and a vacuum pump. The filtration system was composed of two cylinders with a dust feeder on the top and a filter holder in between of the two cylinders. The filtering velocity of filter media was set by manipulating the volumetric air flow rate using the vacuum located at the end of the filtration system and monitored by a rotameter. The experiment was performed using a round fabric filter media with diameter of 47 mm. Filter media made of Teflon needle felt (PTFE) and Ryton were used with their specifications presented in Table 2. Using the experimental filtration rig, a relation between pressure drop and permeability under various filtration velocities were investigated. The pressure drop across the filter media was measured using a differential pressure manometer (Extech Instruments model HD755). The pressure drop was recorded at different filtration velocities from 5 to 8 m/min with material loading from 0.2 to 0.6 mg/mm².

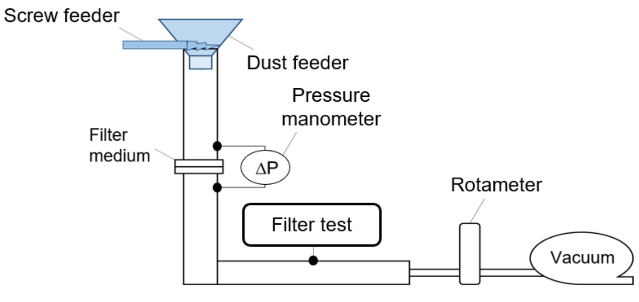



*Figure 1: Schematic diagram of the filtration test system*

*Table 2: Specification of the Ryton and PTFE filter media*

| Material | Ryton (PPS) | Teflon (PTFE) |
|---|---|---|
| Basic weight (g/m²) | 500 | 800 |
| Thickness (mm) | 1.8 | 1.3 |
| Working temperature(°C) | 190 | 240 - 260 |
| Breaking strength (N / 5 cm) | Wrap > 1,200 | ≥ 700 |
| | Weft > 1,300 | ≥ 700 |

### 2.3 Permeability

Air permeability (K), which is one of the basic properties of a porous filter media, was evaluated based on a classic Darcy's Eq(1),

$$K = \mu \frac{u}{\Delta P/L} \quad (1)$$

Where, ΔP is the pressure drop across the filter, L is the filter and dust cake thickness, u is the filtration velocity and μ is the air viscosity (1.81 x$10^{-5}$ Pa.s at 20 ºC). Permeability is closely related to porosity permeability of the filter cake that indicates the relative ease for the gas to travel through the pore space in the filter medium.

### 2.4 Particle penetration

The particle penetration passing through the filter aids cake and the filter media was measured using a GRIMM Aerosol Portable Laser Aerosol Spectrometer (model 1.109). The ratio of the number of penetrated particles with respect to the blank filter under various filtration velocities was calculated based on Eq(2).

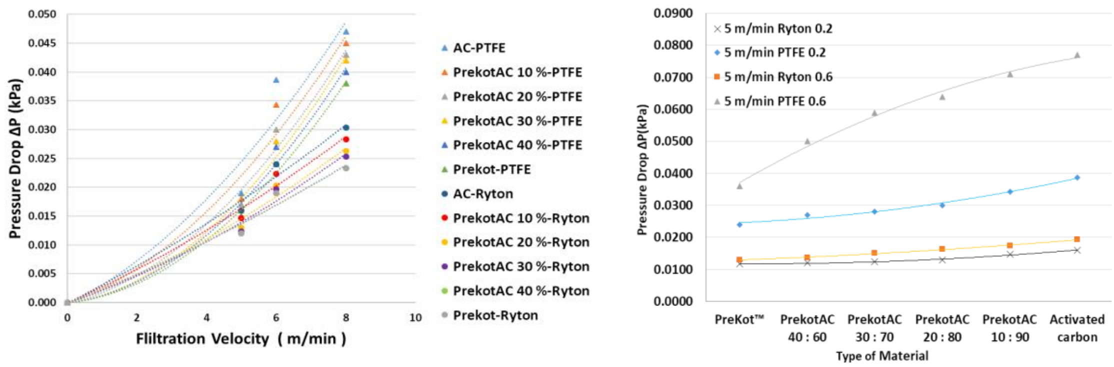
Ratio penetrated particles (Rpp) = Tf / Ti (2)

Where;
Rpp= the ratio of the number of penetrated particles.
Tf= total number of penetrated particles after filter aids was loaded.
Ti= total number of penetrated particles with blank filter before loading.

## 3. Result and discussion

### 3.1 Effect of superficial velocity on pressure drop across filter media

Pressure drop of a filtration unit is an important parameter as it affects the operating cost of the system. Thus, maintaining the right balance between the required emissions control and the operational pressure drop across the filtration system is crucial as the energy consumption of a fabric filter air pollution control system is directly related to pressure drop. Figure 2a presents the pressure drop across the filter aids cake and filter media against the filtration velocity which showed that ryton experienced a lower pressure drop compared to PTFE. Both filter media showed a consistent trend where pressure drop decreases with increase in the percentage of PreKot™ added in the PrekotAC admixture as compared to activated carbon alone. Figure 2b depicts the effect of different filter aids material loading of 0.2 mg/mm² and 0.6 mg/mm² on pressure drop under constant filtration velocity which as expected showed that the pressure drop across the dust cake increases with material loading. This can be explained by the fact that at higher material loading means more of the dust particles arrive at one pore simultaneously, which leads to thicker filter cake and consequently resulting in higher pressure drop across the filter cake.




(a) (b)

*Figure 2: Pressure drop across ryton and PTFE filter media. (a) under various filtration velocities for constant material loading of 0.2 mg/mm², (b) under various material loading for constant filtration velocity 5 m/min*

As depicted in the figure, PTFE drastically presents a higher pressure drop at higher material loading 0.6 compared to at 0.2 mg/mm². Ryton consistently presents a lower pressure drop regardless of material loading compared to PTFE which is contributable to the difference between these two filters. The latter is denser per unit area (in terms of g/m²) than the former which consequently causes a higher pressure drop with increase in dust cake formation. A similar case has also been reported by Hajar et al. (2015) by using PTFE as filter media element, where increasing in material loading, the filter media will experience a higher pressure drop compared to a lower material loading at a constant filtration velocity. As similarly observed in this study, a considerable decrease in pressure drop due to the effect of large deviation in non-uniform particle size distributions of PrekotAC mixture. The porous and fluffy structure of PreKot™ allows easy passage of air flow across the filter aids and filter media with lower pressure drop.

**3.2 Effect on permeability**

Figure 3 presents the permeability of filter aids and filter media under different filtering velocities of 5, 6, and 8 m/min for ryton and PTFE filter media which illustrates that activated carbon has the lowest permeability property for both filter media. PreKot™ has the highest permeability among all filter aids admixtures with ryton showed a higher permeability compared to PTFE in all cases. Park et al. (2012) reported that the permeability of a fresh PTFE of 0.9 mm filter thickness was 5.78 x $10^{-11}$ $m^2$ at filtration velocity of 5 m/min. As a comparison, the value of the permeability of the blank PTFE filter found in this study was 2.88 x $10^{-10}$ $m^2$ at the similar filtration velocity with filter thickness of 1.3 mm as depicted in Figure 3. As expected, ryton was observed to have a lower pressure drop that gave a higher permeability (i.e 4.65 x $10^{-10}$ $m^2$) as compared to PTFE. A high permeability of ryton is due to its porous structure despite of its thickness. Lupion et al. (2014) found that the permeability of PTFE remained practically constant at 9.81 x $10^{-10}$ $m^2$ regardless of the operating temperature of the fabric filtration system, the permeability was higher than what was observed in this study.

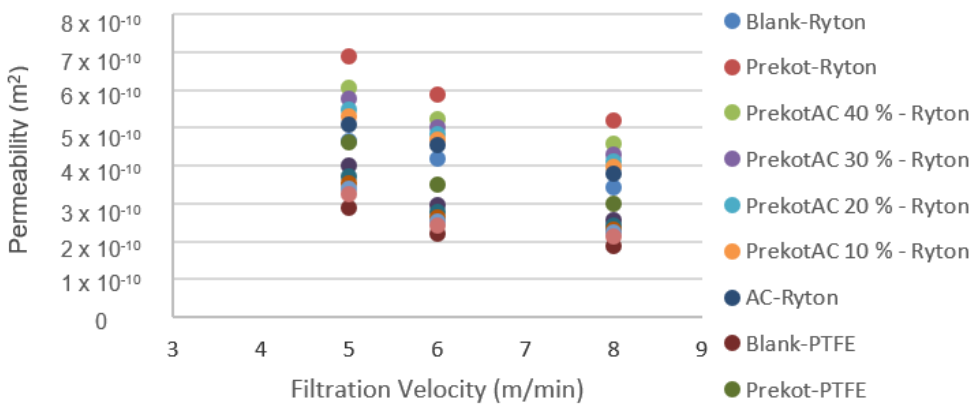


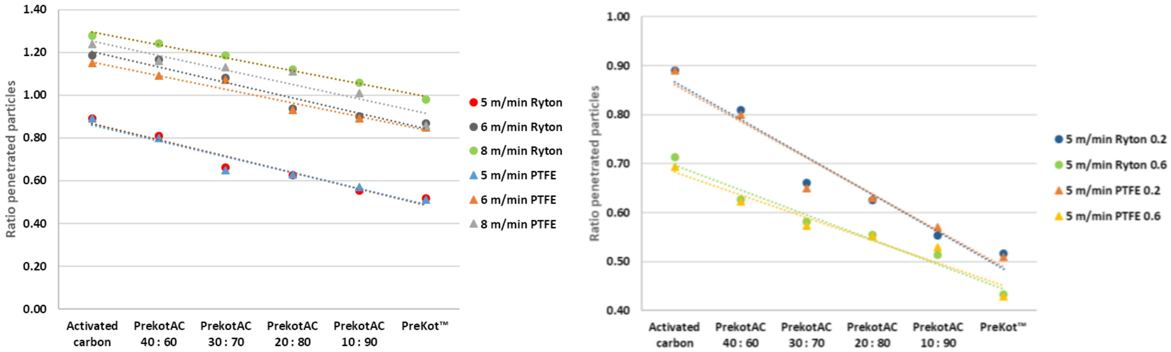

*Figure 3: Permeability of various materials under various filtering velocities at constant dust loading of 0.2 mg/mm²*

The formulated PrekotAC presents a uniform and consistent permeability with 40 : 60 gives the highest while 10 : 90 has the lowest permeability among the combinations. The higher the percentage of PreKot™ in the PrekotAC admixture, the better the permeability of the filter cake becomes. The characteristic of the PreKot™ which is porous, fluffy and multi cellular leads to the increase of the porosity of the filter cake thus, increase its permeability property. This allows high volumetric air flow passing through the medium and reduces the pressure drop across the filter media and contributing to the cake layer being loosely compacted with high porosity and low compressibility. Particle size distribution and shape of the dust material have been put forward to explain the cake structure and behaviour as important factors contributing on cake formation and its detachment ability from a fabric media. This could also be related to PrekotAC mixture characterised by its wide particle size distribution compared to its original material that leads to a better permeability of the dust cake layer where particle size distribution of PrekotAC admixture laid nicely between activated carbon and PreKot™. This reflects the influences of the permeability on pressure drop as it is directly related to pressure drop across the filter medium. PrekotAC showed a consistent increment in pressure drop with PrekotAC10 : 90 has the highest pressure drop with a lower permeability and PrekotAC 40 : 60 presented the lowest pressure drop with higher permeability among the admixtures. Tanabe et al. (2011) reported that higher permeability filters resulting a looser structure of accumulated dust cake layer while lower permeability filters exhibit smaller deposition depth resulting in the more compact cakes structure.

**3.3 Effect on particle penetration**

Figures 4a presents the ratio of the number of penetrated particles through a PTFE and ryton filter media, with the introduction of filter aids materials under constant material loading of 0.2 mg/mm at various filtering velocities

5, 6 and 8 m/min. Both filter media showed a consistent trend where the admixture of PrekotAC having a lower particle penetration compared to activated carbon alone. As observed, PreKot™ has the lowest penetration among all filter aids materials with ryton and PTFE filter media. The Rpp = 1 is a reference marked with dashed line in the figure indicates the ratio of the number of penetrated particles for the filter media alone without the introduction of filter aids. As illustrated in the figure, the activated carbon retains the highest while PreKot™ has the lowest ratio of particles that able to penetrate through the filter media in all cases. It seems that the particle size distribution of the respective material plays a major role in this finding. As previously report by Hajar et al. (2013) activated carbon has slightly more than 80 % of particles of less than 75 µm compared to PreKot™ that has merely 20 % of it. A similar finding was also reported by Innocentini et al. (2009), the collection efficiency for coarser particles are higher compared to finer particles. Lee et al. (2008) found that fine particles can easily penetrating through the filter media compared to coarser particles even using two different types of fabric filter. It was reported by Park et al. (2012) that the total penetration increases as particle size decreases because of lower impaction effect during filtration process in fresh filter media. Activated carbon, which mostly consists of fine particles has higher amount of particle penetration compared to the other filter aids material that has coarser particle sizes Thus, it is expected that activated carbon which predominantly consists of smaller particles has higher number of penetrated particles compared to PreKot™ where fine particles can easily penetrate through a filter media.




(a) (b)

*Figure 4: The ratio of total penetrated particles of PrekotAC filter aids with Ryton and PTFE (a) under various filtration velocities for constant material loading of 0.2 mg/mm², (b) under material loading of 0.2 mg/mm² and 0.6 mg/mm² with constant filtration velocity of 5 m/min.*

As observed, the number of particles that penetrating through both filter media filter increases when filtration velocity is increasing from 5 to 8 m/min where the penetration through the filter media is the lowest at 5 m/min compared to 8 m/min. A higher filtration velocity rate leads to a bigger driving force causing more particles to pass through the open pores of the filter media as observed in the study. It seems that a high filtration velocity allowed more particles to pass through the filter media which is due to deep penetration of particles which consequently able to escape the filter media. Similarly, Simon et al. (2010) reported that particle penetration at a lower air flow rate is less compared to the particle penetration at higher flow rate. The authors stated that higher air flow rate forces fine particles to easily permeate deep into the pores of the filter media compare to at low air flow rate which influence the total number of penetrations. Walsh (1996) also reported that penetration at lower air flow rate is small due to bridges of particles that are formed because of low inertia and long retention time which limit particles from passing through the filter media.

Figure 4b illustrates the effect of material loading of 0.2 and 0.6 mg/mm² on penetrated particles with constant filtration velocity of 5 m/min for PTFE and ryton filter media. PrekotAC 40: 60 has the highest while PrekotAC 10 : 90 registered the lowest total number of penetrated particles even at the highest material loading of 0.6 mg/mm². The total particle penetration for each material follows a similar trend reported by other studies where higher material loading leads to a lower penetration due to thicker filter cake that avoid and block particles from penetrating through the filter media. At higher material loading, a thicker filter cake layer forms on the surface of the filter media which avoid particles permeating deep into the filter media pores. Park et al. (2012) stated that at higher material loading, the particles might be deposited in more packed pattern compared to lower material loading because of the increased coincidence event of particle. The total penetration of particles at higher material loading is small compared to lower material loading. As observed in the study, PTFE which has a denser filter property (in terms of g/m$^2$) gives a lower particle penetration for various material loadings and filtration velocities compared to ryton. The latter presents a lower pressure drop in all cases compared to the former. Pressure drop is a compromised rather than particles penetration when it comes to the actual industrial application.

## 4. Conclusions

The effect of a formulated filter aids material known as PrekotAC on pressure drop and permeability of PTFE and ryton under various high filtration velocities had been investigated and reported in this paper. In all case of material, ryton presents a lower pressure drop compared to PTFE under the various filtration velocities. The existence of PreKot™ in the PrekotAC admixture helps to form more porous filter cake thus reducing the pressure drop even under high filtration velocities and increase the permeability by reducing the compressibility of the cake. The finding suggests that PrekotAC is a potential and suitable filter aids for air filtration system since it has the capability to reduce the pressure drop and enhance the permeability across the filter cake even under high filtration velocity using different filter media. Particle penetration through ryton presents a similar trending to PTFE under the various filtration velocity. PrekotAC admixtures perform a better filtration efficiency compare to activated carbon alone because of the effect of diverse in different particle size distributions of non-uniform particle size fractions for the PrekotAC admixtures. As observed, higher material loading also leads to a lower total particle penetration due to compact filter cake while lower material loading will show looser patterns where more particles can easily permeate through the filter media.

**Acknowledgements**

Both A.Nurnadia and S. Hajar are postgraduate students of the Malaysia-Japan International Institute of Technology (MJIIT) of Universiti Teknologi Malaysia. The postgraduate research fellowship from the institution is acknowledged.

**References**

Desiree A.V., Leonora E.N., Jacklyn C.A., Jomar J.L., 2018, “Bantay Tambutso” project implementation for reducing air pollution: the dmmmsu-nluc, philippines experience, Chemical Engineering Transactions, 63, 97-102.

Hajar S., Nurnadia A., Rashid M., Ammar, M., 2013, Precoating material as filter aids and flue gas treatment for fabric filter, Article Berita Ensearch, April-June 2nd quarter, 4-9.

Hajar S., Rashid M., Nurnadia A., Ammar M., 2015, The Characteristics of a Formulated Filter Aids for Fabric Filters, Powder Technology, 283, 315-320.

Innocentini M.D.M., Rodrigues V.P., Romano R.C.O., Pileggi R.G., Silva G.M.C., Coury J.R., 2009, Permeability optimization and performance evaluation of hot aerosols filters made using foam incorporated alumina suspension, Journal of Hazardous Material, 162, 212-221.

Lee K.M., Jo Y.M., Lee J.H., Raper J.A., 2008, Assessment of surface and depth filters by filter quality, Powder Technology, 185, 187-194.

Lupion M., Rodriguez-Galan B., Alonso-Fariñas F.J., Gutierrez O., 2014, Investigation into the parameters of influence on dust cake porosity in hot gas filtration, Journal of Powder Technology, 264, 592-598.

Margallo M., Aldaco R., Bala A., Fullana P., Irabien A., 2012, Best available techniques in municipal solid waste incineration: state of the art in Spain and Portugal, Chemical Engineering Transactions, 29, 1345-1350.

Tanabe E.H., Barros P.M., Rodrigues K.B., Aguiar M.L., 2011, Experimental investigation of deposition and removal of particles during gas filtration with various fabric filters, Journal of Separation and Purification Technology, 80(2),187-195.

Park B.H., Kim S. B., Jo Y. M., Lee M. H., 2012, Filtration Characteristics of Fine Particulate Matters in a PTFE/Glass Composite Bag Filter, Journal of Aerosol and Air Quality Research, 12, 1030-1036.

Simon X., Bémer D., Chazelet S., Thomas D., Régnier R., 2010, Consequence of high transitory airflows generated by segmented pulse-jet cleaning of dust collector filter bags, Powder Technology, 201, 37-48.

Walsh D.C., 1996, Recent advances in the understanding of fibrous filter behaviour under solid particle load, Filtration & Separation, 33 (6), 501-506.