Formidable fibres

Nathan Schindler, Evonik Corporation, describes how implementing a high-performance fibre material can help cement plants avoid air pollution and meet EPA standards.

The production of industrial goods, like cement, is necessary for the benefits of modern life: roads, hospitals, bridges, long-lasting buildings, walkable urban cities. One of the critical considerations for operators producing cement is to ensure that the harm to the environment is minimised. Every day, the industry gains new insights into its impact on the environment and ways to resolve those impacts. The US EPA recently proposed new standards that, if adopted, will require future reductions in $PM_{2.5}$ emissions.[1] This article will discuss the challenges surrounding the control of fine particle emissions like $PM_{2.5}$ with the pulse-jet baghouse, and address the question as to whether operators can count on filter bags made from materials such as P84® and P84 HT.

Cement plants are in the business of producing particles in the form of cement. Over the decades, the cement industry has taken many steps to mitigate and reduce the impact of particulate emissions on the environment. In 2015 – 2016, the Portland Cement NESHAP (commonly known as Cement MACT) required all existing US cement plants to reduce particulate matter emissions and control mercury emissions. The most common method implemented by cement plants for controlling these emissions is pulse-jet fabric filters on the kiln effluent and many other locations throughout a cement plant.

In January, the US EPA announced plans to continue its trend to reduce the ambient air quality standard for $PM_{2.5}$ particles by lowering the annual ambient $PM_{2.5}$ limit from 12 $\mu g/m^3$ to between 8 and 11 $\mu g/m_3$.

$PM_{2.5}$ particulate consists of fine inhalable particles with diameters generally 2.5 µm and smaller.[2] 2.5 µm is very fine; it is about 30 times finer than the average human hair. The US EPA has estimated that $PM_{2.5}$ emissions cost the US billions of dollars annually in public health impacts.[3] As plants continue to optimise manufacturing performance and ensure that their product and other particulate is captured effectively, the total cost of ownership of pulse-jet collection systems increases.

The four factors of pulse-jet fabric filter cost of ownership

Pulse-jet fabric filters are widely accepted for use in cement plants. They prevent emissions of particulates into the atmosphere in various applications, from high temperature kiln, raw mill, and clinker cooler streams to lower temperature applications like coal mill, cement grinding, and storage silos. Regardless of the composition of the flue gas stream, all pulse-jets operate with the same basic design. The gas or air is induced under negative pressure into the dirty side of the baghouse. The dust laden gases impact filter bags suspended from a tube sheet. Periodically, a blast of high-pressure air is injected into the clean side of the bag, causing the bag to pop and shed the dust layer into the hopper. The cleaned air then exits the filter unit from the clean side where it is typically released into the atmosphere.

When fine particles penetrate the filter media (Figure 1), the pulsing system is unable to effectively remove the particles. Over time, as the bag blinds, the residual pressure drop increases, causing more frequent pulsing. Blinded bags add significantly to the total cost of ownership of operating a filter unit.[4] Selecting the right filter media for an application is critical to the operational success of a plant.

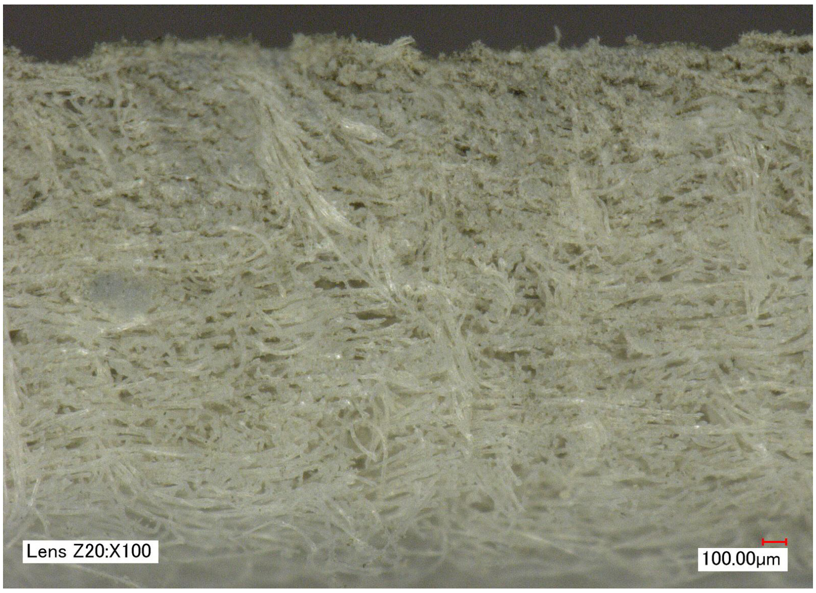

Figure 1. Blinded cement grinding mill felt with e-PTFE membrane.

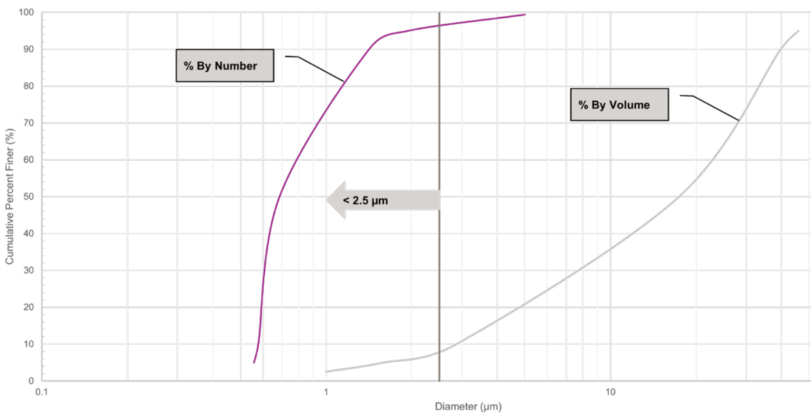

Figure 2. Activated carbon particle size distribution.

Fine particles have an outsized impact on filter performance

$PM_{2.5}$ particulate may be small, but it has a significant impact on the performance of filter media and leads to a significantly higher cost to operate a filter unit. Evonik's experience handling the impact of fine particles dates back to the fabric filter upgrades at the Eskom power plants in South Africa in the 1990s. During pilot testing at the plant using standard fibres in the filter media, the filter units repeatedly tripped on high pressure drops. After evaluating the bags, the plant determined that fine, smooth particles penetrated the felt, blinding the bags.

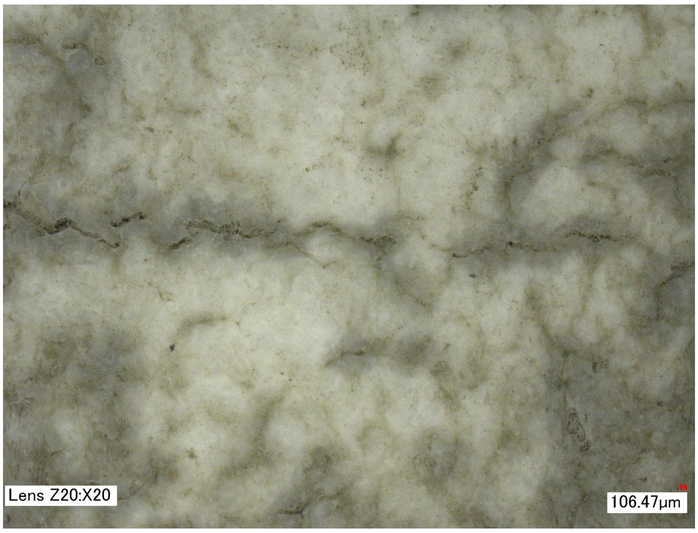

Figure 3. Submicron particles damage e-PTFE membrane.

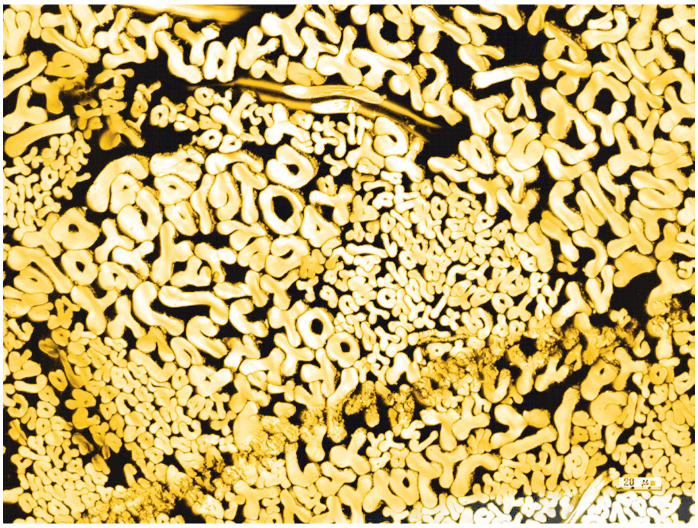

Figure 4. P84 fibre cross-section.

Figure 5. P84 microfibre cap after VDI test.

The plant was able to overcome these issues by integrating P84's irregular multilobal shape as a surface layer. Decades later, the plant continues to benefit from the low pressure drop and long bag life as a result of this filtration solution.

Today, some plants are seeing the impact of fine particles on the operation of their filter units. Some common sources of fine particles in the main baghouse are kiln effluent and clinker cooler fines. Activated carbon, added in many US cement plants recently to control mercury emissions, increases the number of fine particles that the filter media needs to handle. Many plants are also grinding cement to finer and finer grades, like UF-II. Finally, coal mill filters can be impacted by switching to fuel grades, like pet coke, that require finer grinding.

When evaluating the fineness of particles, there are several methods used. The most common in cement is Blaine fineness, which provides a relative particle size when compared to other similar materials but does not provide a distribution of particles. Another method looks at the percent volume of various size particles. This can be useful for evaluating mass loading characteristics, but can be misleading when evaluating filtration performance. A final method evaluates the number or count of particles across a range of sizes. When evaluating very fine materials, this method is more useful in filtration. Take for example commercially available activated carbon (Figure 2). When evaluated on a volume basis, less than 10% of the particles are smaller than 2.5 μm. However, when evaluated on a number basis, more than 95% of particles are smaller than 2.5 μm.

This distinction between number and volume is important in filtration efficiency when dealing with fine particles, because these fine particles are more capable of penetrating into and through filter media than the larger particles.

A common solution to improving filtration performance for applications with fine particles in North America is to apply an e-PTFE membrane to the filtration surface of the bag. The expanded PTFE membrane is a thin, breathable film that is effective in removing particles because it has a large enough pore structure for gases to pass through, but it is small enough to prevent typical-size particles from passing through. It also releases dust well, so unwanted dust does not build up on the bag surface. These

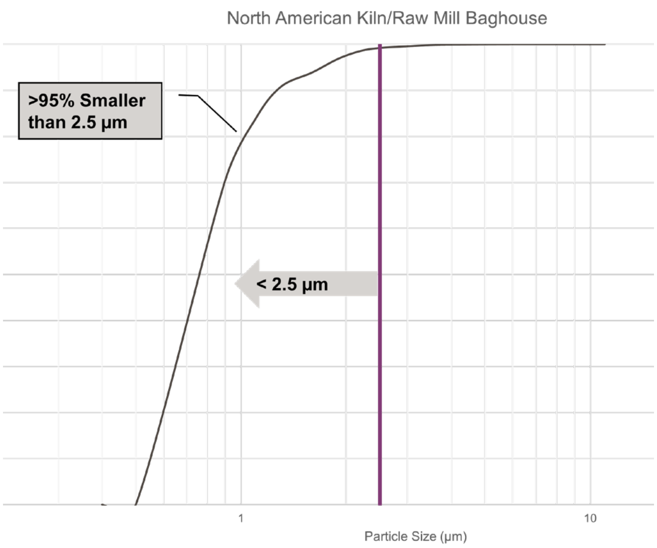

Figure 6. Kiln dust particle size distribution.

Figure 7. Glass/membrane damage.

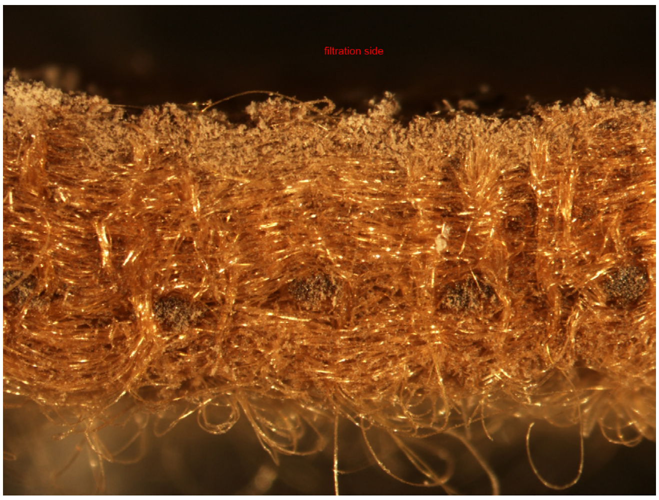

Figure 8. P84 microfibre cap after 42 months.

attributes of e-PTFE membranes are actually detrimental when most particles are fine.

The pore structure of a high-quality e-PTFE membrane has openings in the range of 1 – 2 µm. In one recent application, bags made of fibreglass with ePTFE membrane were installed in a filter unit to capture a clay product consisting of 80% (by count) particles finer than 1 µm. The particles passed directly through the membrane, causing the plant to exceed emissions criteria in a matter of days. Figure 3 shows damage to the membrane layer in a cement grinding application, allowing submicron particles to blind the felt.

Shaping a solution

P84 fibre is well-known in the filtration industry for high-temperature applications and for providing excellent filtration performance. Evonik's P84 fibre product line can handle high temperatures of operation, allowing it to be used in most dry filtration applications. However, what makes P84 really unique is its irregular multilobal shape.

As seen in Figure 4, the cross-section of each P84 fibre is different. This shape allows P84 to build a porous, permanent dust cake on the surface of a bag, preventing particles from penetrating into the felt.[5] P84 micro-fibres (also visible in Figure 4) provide even more surface area preventing the finest particles from being emitted into the atmosphere.

Evonik recently conducted third-party testing to evaluate the performance of filter media constructed with a P84 microfibre cap and an ultra-fine clay product. The well-known VDI test method was utilised to simulate pulse-jet filtration conditions with a high (2 m/min.) air-to-cloth ratio. The rich and porous dust cake formed by the microfibre cap (Figure 5) prevented emissions of the fine clay. $PM_{2.5}$ emissions were below the detection limit, while residual pressure drop and pulse cycle times remained in a good range.

Helping cement plants improve filtration

In North America, one cement plant has been using P84 fibres with the microfibre cap to handle fine particles from the kiln and raw mill at high filtration velocities for around 20 years. Particle size distribution testing confirms that the particles in the flue gas are 1.5 µm on average. When analysed by count, over 95% of the particles are finer than 2.5 µm. In some compartments of this unit, the air-to-cloth ratio approaches 2 m/min., which is much higher than the recommended 1 m/min. maximum range.

During the 2000s, the plant conducted tests with various filter media before adopting a P84 microfibre cap.

The plant evaluated a high-quality fibreglass with e-PTFE membrane. The fine particles and high velocity caused significant damage to the membrane, allowing the dust to completely penetration the fabric.

On the other hand, the P84 microfibre cap filter media provided excellent filtration capacity over 48 months. Figure 8 shows the continued prevention of dust penetration into the filter media over the life of the filter bags while avoiding mechanical damage. As a result, the plant has benefitted from lower operating costs, lower maintenance costs, improved productivity, and lower energy use. These same benefits have also been successfully adopted in cement grinding, clinker cooler, and coal grinding filter units.

Conclusion

The team at Evonik welcomes the opportunity to work with plants to help them optimise the right filter media based on their actual operating conditions.

The company is always exploring new ways to improve P84, including the development of P84 HT for higher temperature resistance and new filter media constructions. It has also developed ways to reduce fuel requirements when using their products to deliver oxygen enhanced air onsite at a fraction of the cost of other systems.[6] ■

References

1. Proposed Decision for the Reconsideration of the National Ambient Air Quality Standards for Particulate Matter (PM), January 6, 2023 – https://www.epa.gov/pm-pollution/proposed-decision-reconsideration-national-ambient-air-quality-standards-particulate.
2. Particulate Matter (PM) Basics – https://www.epa.gov/pm-pollution/particulate-matter-pm-basics
3. Proposed Revisions to National Ambient Air Quality Standards for Particulate Matter, January 2023 – https://www.epa.gov/system/files/documents/2023-01/PM%20NAAQS%20Reconsideration%20Proposal%20-%20Overview%20Presentation_0.pdf
4. SCHINDLER, N. and OGILVIE, K., 'Uncovering the True Cost', *World Cement*, May 2020.
5. HARFMANN, P. and ROFF, G., 'Filter Media Today and for Future Requirements', *Technical Textiles*, Feb. 2008.
6. SCHEER, C. and SCHINDLER, N., 'Pulling a Production Boost out of Thin Air', *World Cement*, December 2022.