High-efficiency filtration in dry/semi-dry FGD plants

By Florin Popovici

P84
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EVONIK INDUSTRIES
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Kurzfassung

Hocheffiziente Filtration in trockenen und halbtrockenen Rauchgasentschwefelungsanlagen


In dem vorliegenden Beitrag wird der Einfluss spezifischer Faserengieigkeiten wie Querschnitt und Titer in Verbindung mit den filtrationsrelevanten Eigenschaften und der entsprechen den chemischen und thermischen Stabilität in Filtern nach trockenen und halbtrockenen Entschwefelungsverfahren in kohlegefeuernten Kesseln dargestellt. Die Partikelemissionen sind ein kritischer Parameter für die Auswahl der Filtermedien, speziell wenn Emissionen unter 5 mg/Nm³ kontinuierlich eingehalten werden sollen.


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General

Coal will continue to remain the most important power source over the next decade around the world and it is expected that its demand and consumption will increase at a high rate. It is still the cheapest source of energy, being associated with economic growth in countries like China and India. Former Eastern Block countries will also see a stable coal demand during the next years. In parallel with coal burning power plants, there is an increasing trend for using renewable sources of energy, especially biomass. Energy from municipal waste is also expected to grow at a high rate in Eastern Europe and Asia. While the demand for coal and renewable sources will continue to rise, the maximum required particulate emission levels are being reduced to values lower than 5 mg/Nm³. In urban agglomerations these limits can be as low as 1 mg/Nm³. Nowadays, the plants require flexibility in relation to the type of coal or renewable fuel used. A single source is no longer a viable strategy and with each type of fuel the resulting combustion gases and fly ashes have different properties in terms of chemical constituents and particle size distribution. This requires an emission control technology operating consistently within the regulatory emission limits for a wide range of process parameters. An electrostatic precipitator (ESP), which is a constant efficiency device, is not suitable anymore, as its performance is directly influenced by inlet dust burden and the value of fly ash resistivity. Different fuel sources produce particles with different resistivity values and this could lead to increased particulate emissions. A fabric filter plant (FFP) is a constant emission control device and represents the only viable technology for the consistent achievement of the present and future tough air pollution targets. In the case of dry and semi-dry flue gas desulphurisation (FGD) plants, the FFP becomes integral part of the FGD system and has a major role in the removal of the SOx and other undesired components from the flue gas. For achieving a successful FFP, the filtration material design and the selection of fibres are of critical importance. The fibres mechanical, chemical and filtration properties associated with the process parameters need particular attention.

Spray dry/semi-dry scrubber

A spray dry/semi-dry FGD system is based on a reactor/scrubber located upstream of the particulate emission control device where calcium or sodium based reagents are introduced for the neutralisation of the SOx components in the flue gas.

The dry/semi-dry FGD systems are designed to perform the following:

- collection of solid particulates in the FFP,
- absorption of acidic flue gas components such as HCl, SOx and HF (neutralisation by calcium or sodium based reagents), and
- adsorption of dioxins and furanes (by activated carbon).

Modern FGD systems use the filter as “fixed bed“ reactor for the absorption and adsorption processes. Therefore, the performance of the filter media has an impact on the performance of the FGD system. We can differentiate two main types of reactions: the primary reaction inside the reactor/scrubber and the secondary reaction in the particulate emission control device. In cases where the boilers are provided with FFPs, the secondary reaction takes place while the gases pass through the bag filter dust cake. With ESPs the secondary reaction has virtually no effect. In order to increase the reaction rate, the dust (with the non-reacted reagent) is re-circulated from the FFP hoppers to the main reactor. Due to the recirculation an increased dust loading has to be collected in the FFP and particular attention has to be paid to the flow distribution in the bag filter area (gas inlet manifold and chambers). The complex dust handling system is an important feature of this plant as up to 90 % of the solids are re-circulated from the FFP hoppers to the reactor. The re-circulated material could be up to 1 kg/Nm³. In semi-dry systems water is added to the reactor in order to improve the reaction rate. All added water evaporates and the system does not require waste sludge handling and processing. There are different types of dry/semi-dry FGD systems, specific to different manufacturers. The main performance criteria are related to the SOx removal efficiency associated with the reagent consumption.

FFPs versus ESPs

The fabric filter is a constant emission device that can tolerate a reasonable increase in gas flow and particulate inlet burden for a short period without affecting the dust emissions. On the other hand, an ESP is a constant efficiency device that cannot tolerate any increase in gas flow or inlet fly
ash burden without negatively affecting particulate emissions. Due to the fact that in a semi-dry scrubber 90% of the material could be re-circulated, the gas dust loading inside the emission control device could be up to 1 kg/m\(^3\) and this will negatively affect ESP emissions. Another important consideration is the secondary SO\(_x\) neutralisation reaction which takes place while the gasses pass through the dust cake in case of an FFP. This is not the case with ESPs, where the gasses have only a limited contact with the dust particles and the secondary reaction is actually non-existent. The contribution of the secondary reaction is shown in Figure 1 where the SO\(_x\) neutralisation reaction rate is shown for ESPs and FFPs. In this case the neutralisation agent is sodium sesquicarbonate (Trona).

It is important to mention that the difference in performance between an ESP and a FFP is even higher in case of a calcium-based neutralisation agent because of its lower reactivity in relation to the sodium-based reagents. In this case the secondary reaction is of even higher importance.

High-efficiency needle felt materials – dust cake filtration

The bag houses associated with semi-dry scrubbers are based on needle felt type bags. A needle felt comprises of a base material or support scrim upon which a web or batt of fibres is bonded by means of a needling process. The batt consists of one or more layers of fibre orientated randomly, where the fibres are arranged in both horizontal directions. A batt can be applied to one or both sides of the support material (scrim). The fibres have to be selected in relation to the process conditions: chemical environment, temperature, dust characteristics and particulate emission requirement. For semi-dry scrubber bag house materials it is critical to select fibres with excellent filtration properties. These have to be present at least on the filtration side of the needle felt. Another critical aspect of the filter material associated with this type of bag house is the fibre surface area. This is related to the fibre finesse and the cross section irregularity. A fine round fibre of 1.7 dtex has a larger surface area than a 2.2 dtex round fibre and a fine multilobal fibre (1.7 dtex) has an even higher surface area than the 1.7 dtex fine round fibre. The higher the surface area, the smaller the pores between the fibres and the higher pores total surface. The trajectory of a dust particle while travelling across the filtration material is also more complex. Fibres with a high surface area, like the P84 multilobal fibres, are critical for the dry/semi-dry FGD bag houses because the fibre structure is influencing the formation of dust cake. Basically, the fibre structure is transferred to the dust cake structure. The latter one becomes porous and also stable during the cleaning event. A porous dust cake with a high surface area ensures a high contact between the gas molecules and the reagent during the passing of gasses through the dust cake. Therefore, the filter materials used for the dry/semi-dry scrubbers must have at least a layer of multilobal fibres on the filtration surface. Figure 2 shows the specific surface area of different types of fibres used in dry filtration.

Due to its excellent filtration properties the P84 fibres also prevent the penetration of fine dust particles into the needle felt. This has important benefits in terms of low particulate emissions, low pressure drop across the bag house, low pulsing rate and the capacity to deal with a high dust loading, common to the dry/semi-dry scrubbers. A microscopic schematic cross section of a P84 material and the associated structure of the dust cake are shown in Figure 3.

Due to the irregularity of the P84 fibre cross section, the filter material charged with dust maintains a high porosity. Another explanation for the high porosity of the dust-laden material is related to the fact that the dust collected between the fibre lobes is not in the way of the flow.
Typical recommended high filtration efficiency materials based on P84 fibres for dry/semi-dry scrubbers are shown in Figure 4. A summary of the filtration mechanism with P84 multilobal fibres is the following:

- The felt constructed from multilobal fine fibres has a high surface area, thus, it is irregular and porous.
- The dust separates in the low velocity zones of the multilobal fibres forming a dust cake.
- The structure of the filter media is transferred to the structure of the dust cake and the dust cake formed by multilobal fibres is irregular and porous. The flow-lines are affected to a lesser extent if compared to the round fibres dust cake.

- The dust cake formed by multilobal fibres is stable and part of it remains attached to the felt during the cleaning phase.

The Evonik filtration test rig (FTR) concept was developed for evaluating mainly filtration properties of different types of filter media. Two test rigs were built and were installed at Eskom South Africa and ENEL Italy power plant bag houses. The tests are performed in partnership with site assistance from the two major power producers. The FTR evaluations assist with the selection of a superior type of filter bag for a specific coal-fired boiler bag house application. The FTR comprises of three main components: platform with suction fans, instrumentation and controls, inspection window adaptor and tube plate bag covers. The FTR schematic is shown in Figure 5.

A test was performed in South Africa at the Eskom Hendrina power plant to evaluate the performance of a P84 based needle felt and two other materials based on PPS round fibres. The FTR test was set up at a filter face velocity of 1.4 m/min with ΔP based cleaning control. In this case the evaluation criteria was the pulsing rate required for each test bag to maintain the ΔP within the set range. The test details and results shown in Figure 6 indicate clearly major differences in terms of pulses per day between the P84 based bag and
the other two PPS bags constructed with fine and normal size (tire) round fibres. Lower pulsing rates induce lower mechanical stresses onto the filter bags and this is directly proportional to the bag life. This direct comparison confirms the superiority of the P84 based bag, already proven by the actual performance of such bags in coal-fired boiler bag houses around the world. Eskom, the main utility in South Africa, is operating some of the largest coal-fired power plants provided with bag houses in the world. Most of them are equipped with bag houses based on P84 blended needle felt bag filter materials. These results were confirmed by other FTR tests performed in Italy in collaboration with ENEL.

**P84 needle felt bag versus glass/membrane bag**

A further FTR test was performed at the Eskom Hendrina power plant for the evaluation of a 100 % P84 needle felt bag and a woven glass with PTFE membrane bag. This time the FTR was set on timer control with pulsing at 20 minute intervals for 17 days/12 minute intervals for the next 23 days and compared in relation to the ΔP achieved by each bag. The results shown in Figure 7 indicate the superiority of the P84 bag after 40 days of operation at 1.2 m/min filtration face velocity. Results with the same level of magnitude were achieved when the same materials were compared in the Italian FTR installed in an ENEL bag house.

### Power plant – Czech Republic – dry scrubbing with bag filter

This coal burning power plant is provided with a fluidised bed boiler, a dry scrubber with calcium hydroxide as a reagent and a bag house. A plant photo and a schematic are shown in Figure 8. The initial set of filter bags was based on a 100 % PPS material. The bags failed on high-pressure drop caused by filter material blinding. It was decided to replace these bags with bags based on a PPS/P84 blended fibres in order to improve the filtration efficiency and prevent the dust penetration into the cross section of the material. Figure 9 shows the condition of the needle felt before the replacement was required and the condition of the new PPS/P84 filter media with a well-defined dust cake and no dust penetration. This bag house is achieving more than five years of bag life operation.

The plant details are listed in Table 1.

**References**


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**Table 1. Plant details of Czech power plant.**

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Fluidised Bed Boiler</th>
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</thead>
<tbody>
<tr>
<td>Filter material</td>
<td>Procon/(Procon)/P84 multi-label + Procon trilobal</td>
</tr>
<tr>
<td>Type of cleaning</td>
<td>Pulse jet – off line</td>
</tr>
<tr>
<td>Gas Flow</td>
<td>550,000 Am³/hour</td>
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<tr>
<td>Temperature</td>
<td>130 to 160 °C</td>
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<tr>
<td>Filtration face velocity</td>
<td>0.75 m³/m² ∙ min</td>
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<tr>
<td>H₂O</td>
<td>up to 7 vol%</td>
</tr>
<tr>
<td>O₂</td>
<td>6 % volume</td>
</tr>
<tr>
<td>SO₃</td>
<td>&lt; 500 mg/Nm³</td>
</tr>
<tr>
<td>NOₓ</td>
<td>&lt; 300 mg/Nm³</td>
</tr>
<tr>
<td>Fuel</td>
<td>Lignite (1 % sulphur)</td>
</tr>
</tbody>
</table>

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**Fig. 6. Eskom/Evonik FTR – PPS/P84 bag versus PPS/PPS bags.**

**Fig. 7. Eskom/Evonik FTR – P84 bag versus glass/membrane bag.**

**Fig. 8. FFP schematic.**

**Fig. 9. Old PPS bags – dust penetration, P84 new bags – clean filter media.**
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P84® and Procon™ fibre blends for superior filtration efficiency.

P84 and Procon blends for filter bags:
Procon fibres with excellent chemical stability offer maximum flexibility when changing coal qualities. Combined with the outstanding filtration efficiency of P84 fibres this material offers long service life and low maintenance cost.

Filtration efficiency:
The unique multilobal profile of P84 fibres ensures that even fine particles are collected and no dust can penetrate the needle felt even at very high dust loads. In combination with trilobal Procon fibres the filter material will show low pressure drop during the entire bag life.

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