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Florin Popovici
Evonik Fibres GmbH
Italy
florin.popovici@evonik.com

High Performance Filtration – In Situ Testing of Filter Media in Coal Fired Boiler Bag Houses

1 Summary / Abstract:

Filter materials and filter bags are designed to suit the process environment and the particulate emission limits required by the air pollution regulatory bodies. Composite materials combining different fibres are used to achieve a filter media with superior characteristics and more cost effective. The presentation gives an overview on the properties of high efficiency filter media and fibres designed for coal fired boiler bag houses including the filtration mechanism associated with high efficiency filtration. Testing of a new filter media is of crucial importance before the large scale implementation in a bag filter unit. The paper describes a new concept and equipment for in-situ testing of bags, filtration materials and fibres, the Evonik Filtration Test Rig (EFTR). With this method, the test bags / materials are exposed to the same process conditions as the filter elements from the main bag house, and the performance of each test bag is monitored individually. Results of various tests are presented and discussed. The EFTR testing is part of a joint research project between Evonik Fibres and Eskom.

2 Introduction

During the past few years coal consumption in power plants has seen a significant growth and it is expected that for the next decade the coal demand will increase at an even higher rate. Most of the growth in coal use arises in China and India. Former Eastern Block countries will also see a high coal demand during the next years. While the coal demand will continue to rise, the maximum required particulate emission levels are expected to be reduced to values lower than 20 mg/Nm^3. In many instances the use of a single coal source is no more a viable strategy and coal fired plants require access to different coal sources. With each type of coal, after the combustion process, the resulting 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. In the case of Fabric Filter Plants (FFPs), 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. The most common type of filter material used in coal fired boiler bag houses is based on a needle felt construction. Fibres like PPS (Polyphenylenesulphide), PI (P84-Polyimide), PTFE (Polytetrafluorethilene) and PAN (Polyacrylnitrile) are used individually or in specific combinations to form the needle felt.

2.1 Needle Felt Materials

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 fibres orientated randomly into open batt, where the fibres are arranged in both horizontal directions. A batt can be applied to one or both sides of the support material (scrim). By blending fibres with good chemical resistance (i.e. PTFE) with fibres characterised by better filtration properties (i.e. PI) we can achieve a stable filter media leading to low particulate emissions. An extra layer of fine fibres characterised by a high surface area could also be added onto the filtration side in order to prevent the penetration of fine dust particles into the needlefelt leading to excessive filter bags cleaning. The bag cleaning applies a mechanical stress onto the bag material and has a direct effect on the bag life. The higher the cleaning rate the lower the bag life. The most common types of needle felts are shown in Figure 1.

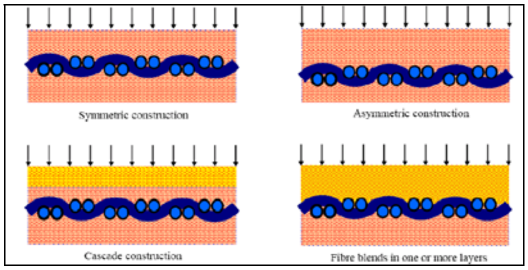

Fig. 1: NEEDLEFELT CONSTRUCTIONS

Dust cake filtration

The needle felt bags have to be pre-coated with special materials before are put in normal operation. The main reason for pre-coating is the formation of a dust cake which, actually, takes over the filtration. This dust layer is named "permanent dust cake". The main role of the needle felt fibres in combination with the pre-coating material is to form a stable and porous permanent dust cake. The most common pre-coating materials used in coal fired boiler bag houses are calcium hydroxide and calcium carbonate. The fly ash accumulates onto the permanent dust cake and it is removed at regular intervals by the cleaning system in relation to the pressure drop across the FFP or a time controller. The fly ash removed by the cleaning system is named "removable dust cake". A non-stable permanent dust cake will lead to the blinding of the needle felt with dust particles penetrating between the fibres in the depth of the material. Some of the dust particles cross the whole needle felt and are released during pulsing creating the so called "pulsing puff". Figure 2 shows a schematic and a picture of a filter material cross section taken from a clean needle felt with a stable permanent dust cake (surface filtration). The filtration process consists of two phases; the formation of the permanent dust cake or pre-coating of bags and the filtration by the permanent dust cake.

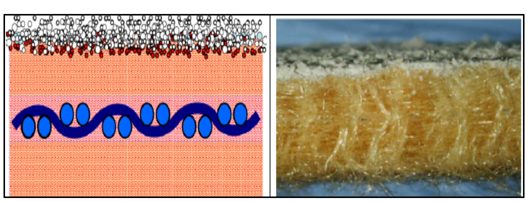

Fig. 2: STABLE DUST CAKE - SCHEMATIC AND PICTURE

High filtration efficiency fibres

It was realised that, in addition to fibre fineness, the cross section of the fibre plays a crucial role in improving the filtration properties of a needle felt. 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 1.3 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. Figure 3 shows the relative surface area of different titre round, irregular multi-lobbed and regular tri-lobbed fibres.

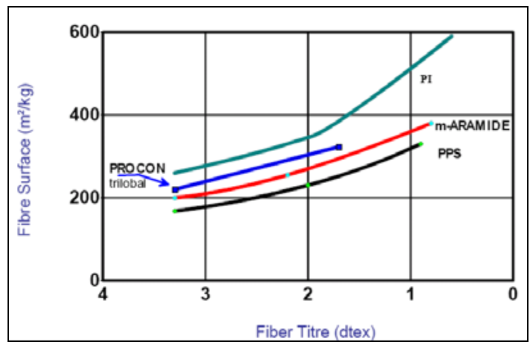

Fig. 3 : FIBRE SURFACE VERSUS FIBRE TITRE (SIZE)

Filtration mechanisms - round versus irregular multilobal fibres

It is well documented that irregular multilobal fibre based needle felts like P84 (PI) have much higher filtration efficiencies if compared to round fibres based filter materials. A study was performed, with assistance from the Technical University of Vienna, to understand the details and exact reasons for the lower particulate emissions and pressure drop across bag houses provided with P84 based needle felt materials. By comparing the projected diameter of two types of fibres with the same titre (weight related to length) we can notice that the irregular multi lobbed P84 fibre has a 30% larger projected diameter than the round fibre. During the needle felt manufacturing process the fibres are entangled in a fleece or web, which is then needle-punched and compacted to form the filter material. In the final product the fibres will lay on top of each other forming a porous and compact material. The felt resulted from the irregular multi-lobbed P84 fibres is more porous than the felt produced with the round fibres. A flow simulation was performed for both types of fibres. The results of the Computational Fluid Dynamic (CFD) model presented in Figure 4 show the presence of low velocity areas.

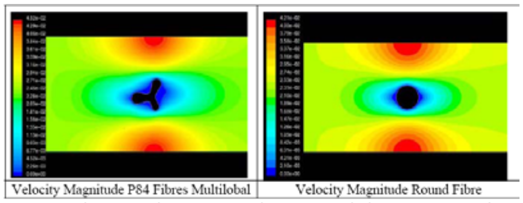

Fig. 4: CFD MODEL – LOW VELOCITY AREAS IN LIGHT BLUE COLOR

The fine dust particles will accumulate in the low velocity areas, actually, charging the fibres and, implicitly, the filter material. Due to the irregularity of the P84 fibre cross section, the filter material charged with dust maintains a high porosity, because the dust collected between the fibre lobs is not in the way of the flow lines (Figure 5). So, P84 based needle felts are able to fulfil even the lowest emission standards. The particulate emission levels are related to the design features of the FFP and the titre of the P84 fibres. The lowest emission is achieved with a P84 fibre titre of 0.6 dtex.

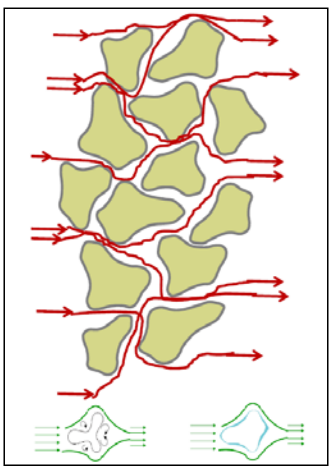
Fig. 5: FLOW LINES THROUGH THE DUST CAKE

In summary, the filtration with multilobal fibres is based on 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 the permanent dust cake.
- The structure of the filter media is transferred to the permanent 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 during the bag cleaning phase.

2.2 Performance test of filter materials in an industrial size test rig

The Evonik Filtration Test Rig (EFTR) was developed for evaluating filtration and chemical resistance properties of three different bag filters. This could assists with the selection of a superior or a more cost effective 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 6.

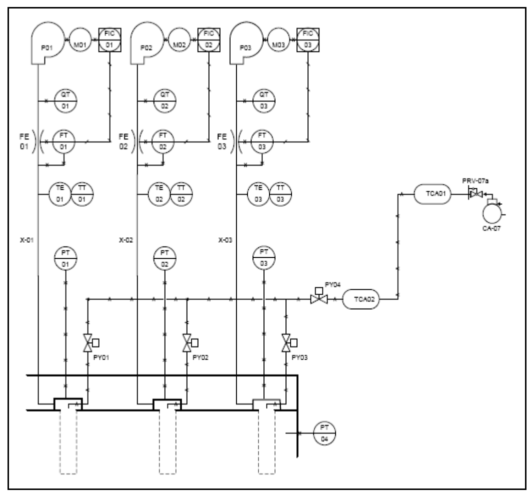
Fig. 6: EVONIK FILTRATION TEST RIG SCHEMATIC

We tested three types of bags in South Africa, at the Eskom Hendrina Power Station Unit 1 pulverised coal fired boiler bag house. Each of the tested bags had a PPS scrim and the inner batt constructed out of 2.2 dtex PPS fibres but with different filtration surfaces as following:

- Bag 1 filtration surface **PPS 1.3 dtex round fibres**
- Bag 2 filtration surface blend of **P84 1.7 dtex multilobal + Procon PPS 1.7 dtex trilobal**
- Bag 3 filtration surface **PPS 2.2 dtex round**

The test was performed at constant flow, the equivalent of 1.4 m/min, and identical ΔP set points. The pulsing started at 13 mbar and stopped at 9 mbar for the first 30 days and 8 mbar for the last two test days. The combined diagram shown in Figure 7 includes the test results after 10, 18 and 30 days and also the test results for the last two days. The main indication for the filtration properties is the average pulse rate for the specific interval (pulses per hour). The results indicate clearly that the bag based on the blend of P84 multilobal and Procon trilobal fibres has a 80 % lower average pulsing rate than the bag based on 1.3 dtex fine round fibres and 50 % lower than the bag based on 2.2 dtex PPS fibres.

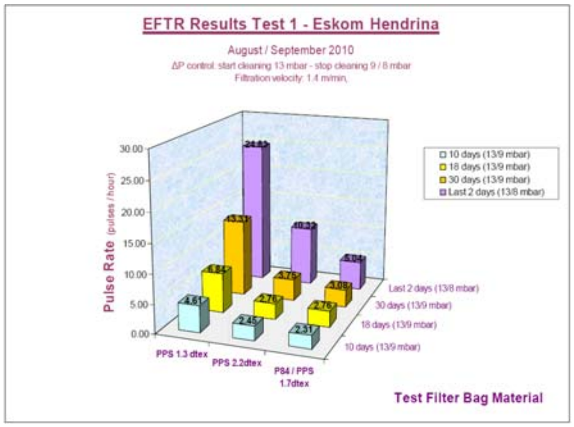

Fig. 7: EVONIK FILTRATION TEST RIG RESULTS – ESKOM HENDRINA P/S

It is interesting to mention that although the set ΔP range was exactly the same for each bag, the 1.3 dtex PPS bag had a higher average pressure differential compared to the other two test bags. The number of pulses influences directly the bag life, as each pulse represents a mechanical stress for the filter material, thus, the bags pulsed less will have a longer life. The superior performance of the P84 multilobal fibre based bag filters is also proven by actual performance of such bags in bag houses around the world.

3 Literature

[1] Popovici, Florin; Mr; Coal-Gen Europe Conference & Exhibition 2011 / Penn Well; Prague, Czech Republic; 15-17/02/2011