Better is the enemy of good.
Das Bessere ist der Feind des Guten.

The aim of the present book was to compile the most comprehensive information possible about the filtration and separation industry and its perspectives. The first part of the reference book gives enterprises in this field the opportunity of introducing themselves and the range of their services. The middle part contains editorial contributions by authors with international reputations. In addition, the reader will find a dictionary of selected technical terms in this book, a subject index and a selection of useful addresses.


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Characterization of long-term filtration behavior of textile dust filtering media

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1. Problem definition
Increasing technical requirements, linked with a consequent increase of environmental protection legislation, have led to a considerable improvement of particle separation from gases. On account of its significance for air quality, in particular on account of the lung deposition, the relatively long stay time in the terrestrial atmosphere and the adsorptive enrichment of substances, which pose a health risk, particular importance must be attached during the emission of dust to the growing fine dust proportion (particle size < 5 µm). Filtering separators count among the preferential dust separation techniques for fine dust. Their constantly rising market penetration is, last but not least, due to the filter media that permit a comparatively sure separation of fine dust. Among the filtering separators, cleaning filters serve for the separation of particles of gases with high dust contents of some g/m³.

Long time operating performance of cleaning filters is sustainably influenced by numerous system parameters, operating parameters and substance parameters whose effects are closely tied together and are only barely distinguishable from each other. A procedural special position is being attributed to the right selection of the filter medium. Although cleaning filters have achieved a high filtering-related level of development, the filter media selection and the design of de-dusting plants occurs even today primarily on the basis of empirically gained knowledge. Nevertheless, this is related to bigger imponderabilities for the building and the operation of a de-dusting plant. Therefore, there is an attempt to minimise the risks by pretests.

Tests of filter media in test rigs serve the selection of suitable filter media, the evaluation of large-scale technical filtration properties and the determination of operating states that are as stable as possible. Nevertheless, the determination of industrial operating states of cleaning filters on the basis of the filter test results in laboratory filter test rigs is possible mostly in a conditional manner only. The reasons for it are the complex operating conditions of large-scale plants. For instance, the exhaust gas composition, the variations in operating conditions, the form of the filter elements and their cleaning can only be partially reproduced with laboratory test rigs.

The filter test rigs planned for these tests and test specifications are determined, i.e., by the following national directives: VDI 3926 (Germany) /1, 2/, ASTM D6830-2 (USA) /3/, JIS Z 8909-1 (Japan) /4/ und GB 12625 (China) /5/. At the moment, an ISO-standardization process is underway which is supposed to culminate in an ISO standard, with the objective to ensure an international comparability of the different filter media test standards /6/.

In the variously designed test rigs, the test specimen that are available as planar filter elements are supplied with a dust-containing raw gas flow with constant filter face velocity. The dusted filter medium is periodically cleaned on-line, mostly through a compressed air pulse from the pure gas side. The temporal change of the pressure loss via the filter medium is continuously recorded. The mean pure gas concentration is gravimetrically determined by means of absolute filters.

In the original test specifications of the VDI 3926 (1994) /1/, 10 and/or 100 filtration cycles are planned for the filter test. If one considers, however, an average industrial action time of approx. two to four years, approx. 200,000 to 400,000 filtration cycles result in realita /7/. Results about filtration behaviour based on 10 and/or 100 filtration cycles are therefore not very conclusive for the assessment of long time filtration behaviour.

To be able to better predict the long time filtration behaviour of filter media, efforts are being made to change the existing test standards in such a manner that greater significance is attached to the artificial ageing of filter media.

2. Processes during ageing
The aging of a filter medium generally denotes the irreversible change of filtration properties of the medium during industrial long time operation. One distinguishes, on this occasion, between chemical ageing, mechanical ageing and ageing by irreversible filter means blockage, and a combination of the different ageing versions limits the service life of the filter media.

In the course of chemical ageing, the filter media are permanently damaged among other things by heat, vapour, acids, alkaline agents, solvents, process gases
and flue gas, air and light. Based on appropriate test procedures and in the knowledge about the industrial suitability for use, manufacturers inform in data sheets, among other things, about chemical resistance, thermal load capacity and about the combustibility of fibre materials and the filter media made from them.

Mechanical ageing during long time operation is caused above all by mechanical stress on the filter medium in the form of tractive forces and shear rates during the cleaning cycles. With on-line cleaning, a short-term compressed air blast is introduced into the filter element against the filtration direction, and adhesive dust layers are removed by the return of the flow direction as well as by acceleration of the filter medium. As a result of the acceleration and/or delay of the filter medium and its deformation associated with this, a partial relaxation of the fibre compound structure results, which can even lead to tearing of the filter medium. In addition, thermoelectric voltage, among others, can weaken the structural integrity of the filter medium.

The ageing of the filter medium by irreversible filter blockage is the immediate effect of a lasting particle deposition in the filter fibres on account of insufficient cleaning. This becomes apparent in a constantly rising residual pressure loss (pressure loss immediately after cleaning has occurred). Irreversible blockage not only influences residual pressure loss, but - through the two-dimensionally inhomogeneous distribution of the dust - it also has an impact on pressure loss via the dust cake building up and shortens cycle time as a result. Owing to the higher pressure drop and the faster pressure drop increase, a higher power demand results for the vacuum fan for the maintenance of the filter inflow velocity and/or an increased compressed air need for the cleaning of the dust cake, and particle penetration also increases owing to the rising number of cleaning cycles and hence mean dust concentration in the pure gas also gets worse. The irreversible blockage of the filter medium becomes apparent in the operational long-term use of the filter medium, even more clearly, the longer the filter medium is used, and leads, finally, to interference with the operating performance of the filtering dust collector that is no longer negligible.

3. Effects of artificial ageing

In order to be able to estimate long time filtration behaviour of filter medium under observance of moderate overall testing times and an easy execution of the test, an ageing (continuous load phase) of initially more than 10,000 time-controlled cleaning actions every 5 seconds was introduced in the test specifications on the filtration behaviour of dust filter media \(/\). Studies have shown, however, that aging of filter media with cycle times of only 5 seconds results in lower residual pressure drops and lower average PM2.5 pure gas concentrations than an ageing process with cycle times of 30 and/or 60 seconds \(/\). This can be interpreted as an immediate result of dust feeding cycles that are too short, as a result of which there is only insufficient dust deposit on the filter fibres. Hence, other blockage mechanisms become effective than those that have an influence on the long time filtration behaviour of filter medium in industrial use. As a result, cycle time was extended from 5 to 20 seconds and, at the same time, the cycle number of ageing was reduced to 2500 in order to consistently maintain a moderate overall testing time. One hopes to be able to better forecast the long time filtration behaviour of filter media by this approach \(/\).

Studies concerning residual pressure drop behaviour within the scope of the ageing of textile dust filter media make clear that the test apparatus used do significantly influence ageing results \(/\). Thus, for example, VDI filter test rig 1 – with the same cycle figures but on account of the different filter sample size and different apparatus-based versions of pulse-jet cleaning – presents with lower residual pressure drop increases than the JIS test rig, with the otherwise same test conditions (fig. 1).

A uniform criterion for the assessment of ageing efficiency has not been determined to date yet. Further studies on long time filtration behaviour of filter means are necessary for the determination of such an academically sound assessment criterion on ageing efficiency.

![Fig. 1: Comparison of residual pressure drop development during filter means ageing in the VDI 3926 type 1 test rig and in the JIS Z 8905-1 test rig (according to /77)]](image-url)
and for the determination of the accompanying test conditions.

The ageing of a filter medium by no means has to occur in one of the customary filter test rigs. It can be also carried out in an ageing chamber specially designed for this purpose (Fig. 2), in which the filter medium specimen is supplied with test dust for 100 seconds per cycle with test dust and is afterwards subjected to on-line compressed air cleaning (time-controlled cleaning), while the filter face velocity remains unchanged during the numerous cycles.

During studies on the ageing behaviour of filter medium with the help of such an ageing chamber, it was shown that the temporal pressure drop increase does not lead to an invariable value (stationary operating state), but increases extremely strongly from a certain point in time onwards, on account of a complete filter means blockage. The time of the extreme pressure drop increase in a filter means test specimen is determined by the size and the cooperation of the parameters influencing the filtration pressure; and the filter face velocity, the cycle time, the choice of test dust and the cleaning conditions are all exceptionally important.

The time of the extreme pressure drop increase remains unrecognised with most filter media under normative specified filtration speeds of 2 m/min. and a cycle time of 20 sec.- with 2,500 cleaning cycles, this corresponds to an ageing time of approx. 14 h. Nevertheless, its appearance can be noted at higher filter inflow velocities and longer cycle times already within the l.g. time span. The steady increase of the pure gas-sided negative pressure as a result of the permanent filter means blockage during ageing can be held responsible for the extreme pressure drop increase. This pure gas-sided negative pressure damps the pure gas-sided excess pressure generated as a result of the cleaning pressure surge generated at short notice, so that the dust-fed filter means is being increasingly insufficiently cleaned. This happens until the cleaning success by the pure gas-sided compressed air is missing totally and, consequently, the pressure drop via the filter medium increases suddenly (Fig. 3).

Fig. 2: Schematic view (on the left) and photograph of the ageing chamber (on the right) /9/

Fig. 3: Temporal pressure drop increase of a membrane filter medium during time-controlled ageing as a function of filter inflow velocity

Filter medium: Membrane/Glass fibre test dust: Pural NF (d90 = 8.6 μm) Tone pressure: 0.5 MPa Valve opening time: 60 s Cycle time (opening): 100 s Ambient gas concentration: 0.5 g/m³ Filter face velocity: 2.1 – 2.7 m/min
From the interpretation of the results of ageing tests in different filter media with the help of an ageing chamber, it becomes clear that the ageing parameter, defined as a time of the extreme pressure drop increase, can be used for the assessment of ageing behaviour of filter medium /10/. The ageing parameter unitizes information about the temporal course of the residual pressure drop and the cake pressure drop in one single parameter.

The dependence of the ageing parameter on filter inflow velocity can be made clear by the ageing performance curve (fig. 4). In order to keep testing time relatively short, the ageing performance curve of a filter medium is determined mostly at higher filter face velocity than is usual in industrial practice. However, the ageing performance curve can be simply extrapolated for lower filter face velocities without having to carry out long-term ageing tests for this. The mean pure gas concentration during the ageing process and the residual dust mass deposited in the filter medium, in respect to the permeated gas volume, are other possible parameters for the comparative assessment of long time filtration properties of textile dust filtering media.

The right selection of test dust, comprising different materials with different grain size distribution, and their impact on the ageing process of textile filter media, are the object of current studies.

Literature


3/ ASTM D6830-2: "Standard test method for characterizing the pressure drop and filtration performance of cleanable filter media", ASTM International, 190 Barr Harbor Drive, PO Box C703, West Conshohocken, PA 19428-2959, USA


9/ Palas: "Alteurungskammer zur Untersuchung des Langzeitsfiltrationsverhaltens von textilen Staubbildern", Palas GmbH, Greshbachstraße 3 b, D-78229 Karlsruhe


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