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Industrial particulate de-dusting plants, optimization in operating cost

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Abstract

With respect to global discussions about climate change, efforts for reducing CO_2 emissions and associated emission trading, it makes sense to bring into focus the power consumption of large facilities. It is particularly useful to take a closer look at air purification facilities. Conveyance of gaseous process and exhaust air flows, and the associated pressure loss in the de-dusting systems, causes the bigger part of electric energy consumption of industrial plants. Pressure loss reduction in filtration plants is a non-negligible factor for increasing energy efficiency. Combined with a suitable cleaning system and modern surface filtration media, energy requirement for de-dusting plants can be significantly reduced. The determination of filtration data by using standardized basic investigations and measurements in the field, gives the opportunity to characterize de-dusting plants in terms of energy and operating cost reduction. This applies to new and existing filter systems.

Especially for large gas volumes, bag filters has become indispensable in numerous industrial processes for separating particles from gas streams. They provide the benefit of meeting current and future emission limits in a single process step, even at highest raw gas dust content. In addition, the number of installations increases steadily for product recovery from exhaust air. The investment in modern jet-pulse bag filters will pay off after a short period for many applications due to the ability to recover valuable products contained in the exhaust air stream.

Introduction

At the beginning of the industrial application, bag filters were cleaned manually or by mechanical shaking or vibration, later by large reverse air flows. Only the introduction of the jet pulse cleaning system has provided a pressure pulse for a highly effective removal of the filter cake and for the regeneration of the filter media. In addition, the jet pulse cleaning system represents an increase in energy efficiency by itself. Further studies consider different ways to reduce the pressure drop across a filtration unit and the energy consumption of the whole filter system. The following measures were included:

- application of flow-optimized injector systems in order to use the tank pressure optimally and implement the pressure pulse
- reducing the requirement of compressed air for Jet-Pulse cleaning, also by regulation of the tank pressure
- reduction of the pressure drop across the filter housing, including the filter inlet and outlet and the filter media

The following considerations are focused on reducing the pressure loss caused by the filtration separator, since the power consumption of the main fan is directly dependent on the pressure loss. This reduction of the pressure loss leads to significant savings in electric energy.

Influence of different measures on the energy efficiency of filtering separators

In addition to the ongoing research on injection systems, considerations have been made to reduce the pressure losses due to flow resistances in the filter system. Further on, investigations on filter media have come to the fore. A large number of investigations particularly regarding the reduction of the pressure loss were carried out during filtration processes. Depending on the operation conditions, the pressure loss caused by the filter cake can account for over 50% of the total pressure loss of the filter plant.

Cleaning system

First, the influence of the cleaning system is considered. In general, the compressed air for regenerating filter media is stored in a pressure vessel and passed via quick-release membrane valves in a nozzle tube. The compressed air is distributed and flows through special nozzles. Fig. 1 shows a Jet pulse cleaning system with the patented Coanda Injector [1]. In simple systems, the fast flowing air formed a so called free jet. This forms a cone shape and the central stream is aspirated and swept along the surrounding medium (air or gas). The form of the nozzles is crucial for the use of directed compressed air jet. In addition to injector systems for preventing propulsion jet necking and Coanda Injector systems, many different injector systems are used.

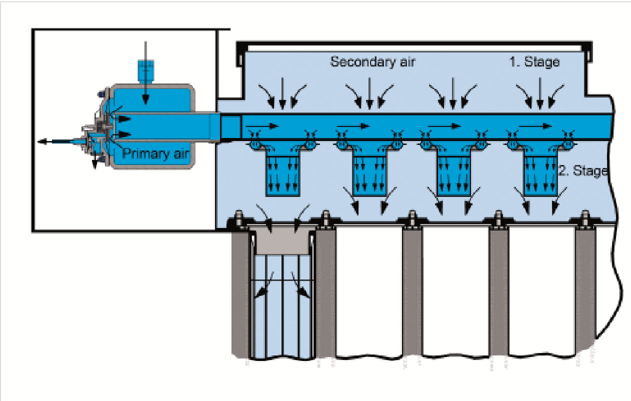

Fig. 1: Jet pulse cleaning with the patented Coanda Injector

Coanda Injector systems make use of the so called Coanda effect. The conducted compressed air leaves the annular gap in inward radial direction and is diverted in axial flow direction. The flow in proximity to the walls creates an under-pressure in the centre of the injector. Further on, secondary air is swept along and a propulsion jet is created. As a result, large amounts of reverse air are generated to achieve optimum cleaning of the filter media [2]. Fig. 2 gives a display of a filter bag in cross sectional view.

On the left side, the filtration phase is shown and on the right side the cleaning phase is displayed. At this stage, the filter bag is expanded by a jet of compressed air. The filter cake breaks up and is detached from the surface of the filter media. Raw gas concentrations were measured and average concentration calculated for evaluation of the influence of injector systems on the residual emission of filtration separators.

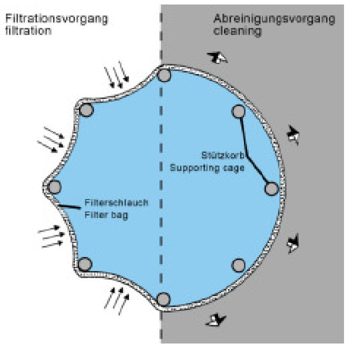

Fig. 2: Filtration and cleaning process of a filter bag by compressed air

In comparison with a nozzle injector system, dust concentrations in clean gas streams could be reduced by approx. 85 % with the Coanda injector (Fig. 3).

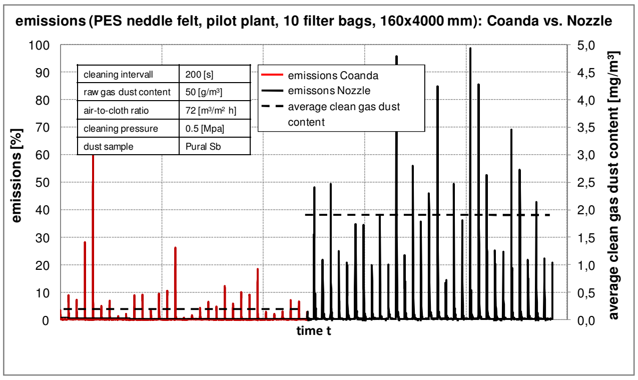

Fig. 3: Influence of injector system on clean gas concentration

This result gives a hint to a gentle de-dusting performance by using Coanda Injector systems. This outcome can be qualitatively explained by an increased amount of reverse gas and a decreased “carpet beating effect” [3].

Cleaning controller

A further aspect for increased energy efficiency is the application of a system specific de-dusting control. The pressure loss of the facility will be monitored within a give measurement period. Next, the required pressure for the de-dusting procedure will be adjusted in the pressure tank. As a result, the tank pressure increases or decreases depending on the required amount of pressure for the de-dusting procedure in order to maintain a steady state operating condition.

Operation mode

Taking filtration units out of the process (offline operation) can reduce the required cleaning pressure in comparison to online operation. This can be realized by semi offline operation, as well. In semi offline operation, only the clean gas area (filter head) will be blocked from the gas stream. Thus prevents re-entrainment of dispersed dust particles after the compressed air jet to a great extend. Fig. 4 illustrates the requirement of cleaning pressure during offline operation of a filtration separator. The curves show the local inside pressure of filter bags with a length from 4 m to 12 m. The tests were carried out with cleaning pressures (inside the pressure tank) ranging from 0.1 MPa to 0.5 MPa [4]. Former studies conducted with limestone dust in a pilot plant revealed that a minimum bag inside pressure is sufficient to detach a filter cake from filter media surface [5].

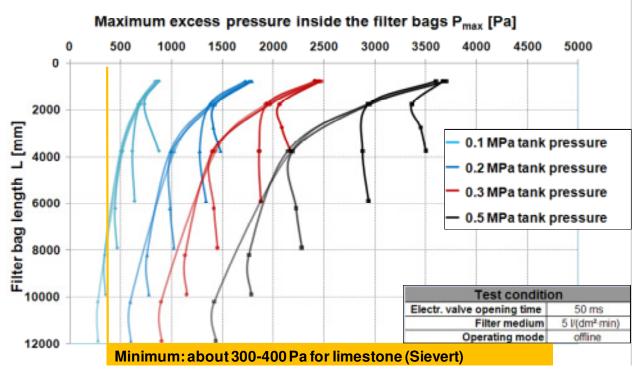

Fig. 4: Max. excess pressure inside filter bags up to 12 m length, offline operation mode

Furthermore, the feasibility is shown to regenerate filter bags of 12 m length during offline operation by using modern injection systems and system controls attuned to them. A cleaning pressure of 0.2 MPa was sufficient. To maintain a reliable operation of filtration separators, it is necessary to reach a steady state. Depending on the process conditions (temperature, type of dust, etc.) other operation modes are possible in order to reach a steady state.

Filter media

An important factor in regard to energetic considerations is the choice of filter media in use. The bigger part of pressure loss inside the filtration separator is caused due to irreversible inclusion of dust particles inside the filter media and formation of the filter cake. The overall pressure loss was significantly reduced by extensive investigations on filter media, their optimization in regard to surface filtration mechanisms and finally their application. The initial pressure loss of conventional filter media is of relative low amount. However, the pressure loss strongly increases with proceeding operation. The use of microfibers on the in-flow side provides benefits for reducing the pressure loss. The microfibers are collocated between the bag surface on the raw gas side and the supporting tissue [6]. As a result, the pressure gradient is of lesser amount during the first filtration phase in comparison with conventional filter media. Filter media with an ePTFE membrane have low pressure gradients as well, but the initial pressure loss is relative high due to smaller pore size und irreversible dust inclusion (Fig. 5). These investigations were conducted using a VDI 3926 Type 1 test facility (Fig. 6). Media deterioration was carried out by 36.000 de-dusting procedures with a cycle time of 25 s and a cleaning pressure of 0.5 MPa. The air-to-cloth ratio was adjusted to a value of 120 m/h and particle concentration was adjusted to a value of 10 g/m^3. These values exceed the guidelines of the ISO-Norm. The results of these investigations lead to the launch of the "optimized microfibre" filter media. Fig. 7a gives a display of the differential pressure progression inside a pilot plant during quasi-stationary operation and application of filter media of varying quality. Fig. 7b shows the differential pressure progression of "optimized microfibre" filter media material with varying cycle times.

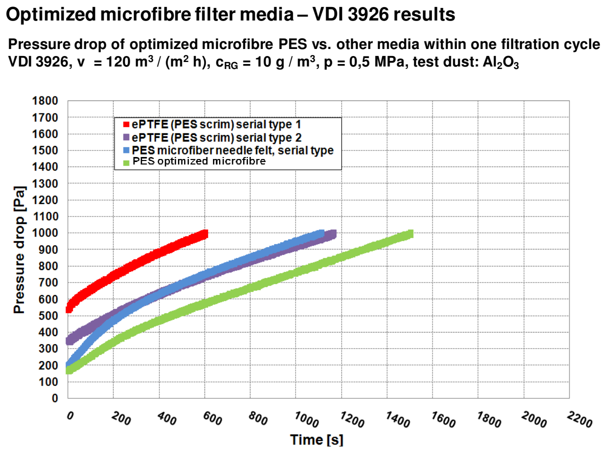

Fig. 5: Differential pressure progression, single-sequence in semi offline operation mode (VDI 3926, Typ 1 test)

Fig. 6: Test facility, VDI 3926, Typ1

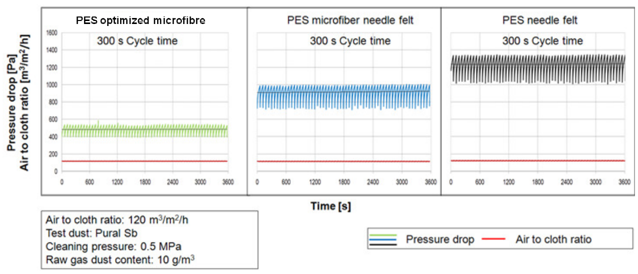

Fig. 7a: Differential pressure progression of pilot plant with varying filter media quality

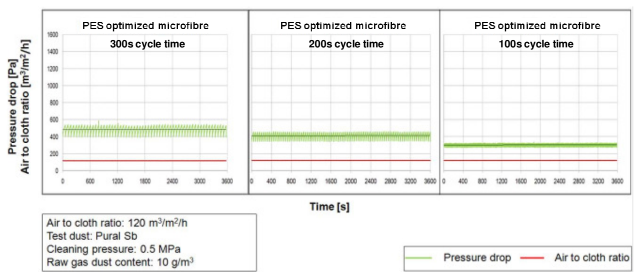

Fig. 7b: Differential pressure progression of "optimized microfibre" filter media material with varying cycle times

It becomes clear, that the application of "optimized microfibre" filter media material and the reduction of cycle times can lead to a significant reduction of plant pressure loss by factor 4 (Fig. 7c).

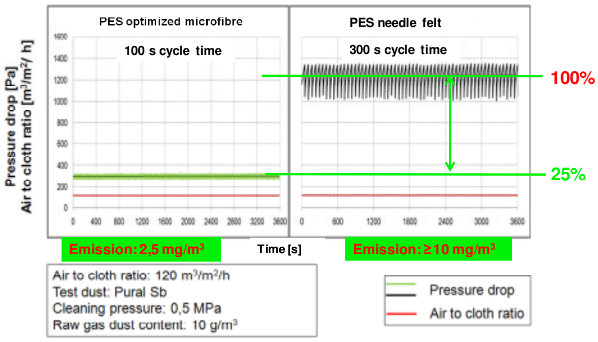

Fig. 7c: Potential saving: application of "optimized microfibre" filter media material, reduction of cycle time and reduction of plant pressure loss by approx. factor 4

Filter expert system

According to this, considerable potential savings of electric energy become apparent in regard to the power consumption of the main fan. Therefore, life-cycle costs (LCC) decrease by using appropriate filter media and optimized cleaning systems. This gave the possibility to develop a system for estimating the optimal operating parameters for filtration separators in order to minimize the operation costs (Filter Expert System). The outcome of a case study regarding the de-dusting of a rotary kiln combined with raw meal mill at high raw gas dust content is shown in Fig. 8. The filtration separator was equipped with filter bags of 8 m length [7]. The de-dusting facility is a huge jet-pulse filter which is using enhanced energy efficiency.

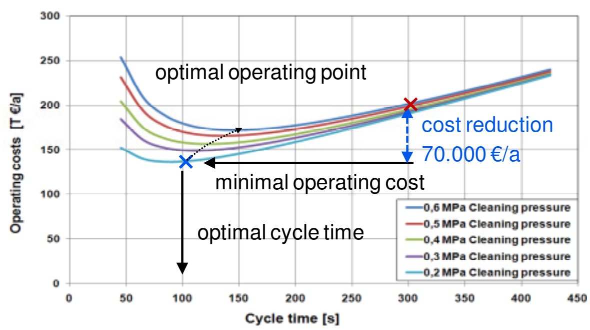

Fig. 8: Optimal operating point in dependence of the cleaning pressure: Case study of de-dusting of a rotary kiln combined with raw meal mill at high raw gas content, equipped with 8 m long filter bags.

Another example for a facility used for de-dusting large exhaust gas streams is displayed in Fig. 9.

The facility is located in India and capable for de-dusting flow streams up to 2,100,000 m³/h at a maximal temperature of 240°C. The filter bags in use of polyimide web and polyimide scrim are of 8 m length and posses a coating weight per unit area of 600 g/m^3. Even after three years, the differential pressure of approx. 4.5 mbar is considerably low.

Fig. 9: De-dusting facility in India

In addition to the analysis of newly built plants, it is possible to analyze and optimize older plants, too. This applies for the retrofit of electrostatic precipitators into filtration separators in order to meet environmental regulations as well at minimum investment. Fig. 10 shows a plant before and after the retrofit.

Fig. 10: Retrofit of an electrostatic precipitators to a Jet-Pulse bag filter

Conclusions

According to the investigations, the feasibility of optimizing de-dusting facilities in regard to their demand of electric energy became apparent by combining different measures. The choice of filter media combined with the reduction of cycle times has a big influence here. Thus, flow resistance und demand of electric energy can be significantly reduced. Depending on the process, the operating data and plant size, potential savings can account for 40 % in regard to the operating costs. Further on, this technology provides an alternative to increasing the air-to-cloth ratio and therefore, size reduction of the filtration separators. The experience is complemented by the development of the Filter Expert System. This engineering tool estimates potential savings by definition and comparison of parameters in regard to the consumption of electric energy and is applicable for existing and newly built filtration facilities. It is important to have exact knowledge about the parameters and operating data and to cooperate with the plant manager in order to implement the optimization measures. The expert system focused on costs related to main fan motor energy and compressed air. The next expansion stage will include research into further de-dusting applications, depreciation, services and bag replacement for full filtering installation [7, 8].

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