LÜHR FILTER

Operating experiences with the use of fabric filters as fine cleaning stage for alkalis, dioxins, SO_x and heavy metals downstream sinter plants

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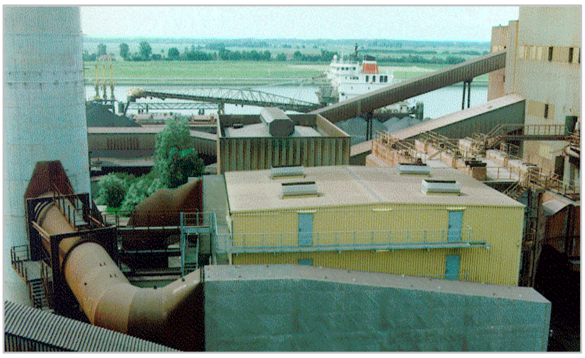


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Summary

Purpose:

The nowadays requested emission limit values at new and existing plants for the gas cleaning systems downstream sinter strands can often only partly be maintained with the currently installed systems – in most of the cases multiple-stage electric precipitators. Very often the integration of an additional fine cleaning stage becomes necessary for the observance of emission limit values, i.a. for alkalis, dioxins, SO_x and heavy metals.

Methodology:

With regard to the process technology, dry and conditioned dry procedures have meanwhile become accepted for these applications. In most of the cases, CaO / $Ca(OH)_2$ and activated coke are used as additive powders. All procedures offered on the market use a multiple re-circulation of the particles separated in the filter into the upstream installed reactor, in order to increase the efficiency. A process variant several times realised in the meantime is the LUEHR FILTER Conditioning Rotor – Recycle Process. In Europe four plants are in successful operation and another four sinter strands are now under construction.

Results:

This lecture introduces two plants in Europe, realised as Conditioning Rotor – Recycle Process.

- ArcelorMittal Bremen – commissioning in 1993
- Voest Alpine Stahl Donawitz – commissioning in 2002

The operating results of both plants are discussed with regard to the achieved degree of separation for the separate components, the plant availability and the consumption figure for additive.

Keywords:

Sinter plant - Emissions - Flue gas treatment - SO_2-removal - dioxin-removal

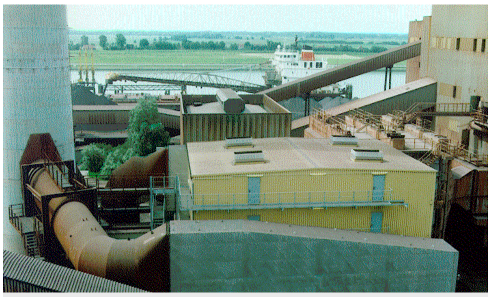
1 Today's requirements on emission limit values regarding the off-gas from sinter plants

Operators of sinter plants in Europe and Asia are increasingly forced to observe tightened emission limit values in the off-gas escaping from sinter strands. This mainly concerns the limit values for dust, heavy metals, dioxins/furans as well as SO_2. In Asia and occasionally also in Europe, additional measures regarding the NO_x reduction are discussed. The so far existing gas treatment systems – in most of the cases multi-stage ESP – are not able to meet the new requirements. Fine cleaning stages have increasingly to be installed downstream electrostatic precipitators.

In practise, different solutions of process technologies have been tested:

- Wet systems
- Gravel bed filters
- Fabric filters with upstream installed reactor

Compared to other technologies, the latter got accepted as an efficient and reliable solution in the course of the last years. In Europe already seven fine cleaning stages realised as fabric filters with sorption reactor are meanwhile in operation. Further plants are in process of realisation. The replacement of a wet system by a fabric filter with sorption reactor is planned at a European site. This technology is also used in Asia (Korea, China and Taiwan).



Arcelor Mittal Bremen / Germany
Commissioning: 1993

Voest Alpine Stahl / Donawitz / Austria
Commissioning: 2002

Trinecke / Czech Republic
Commissioning: 2008

Dragon Steel / Taiwan
Commissioning: 2010

Pic. 1: Examples for realised plants

This lecture presents a procedure – the conditioned dry sorption with the LUEHR Conditioning Rotor – Recycle Process – as a variant for the system fabric filter with sorption reactor and discusses the operating experiences gathered from two plants which have been in operation for several years. Already four sinter plants have been equipped with this technology (pic. 1), another five plants are currently in the engineering phase and/or in process of installation.

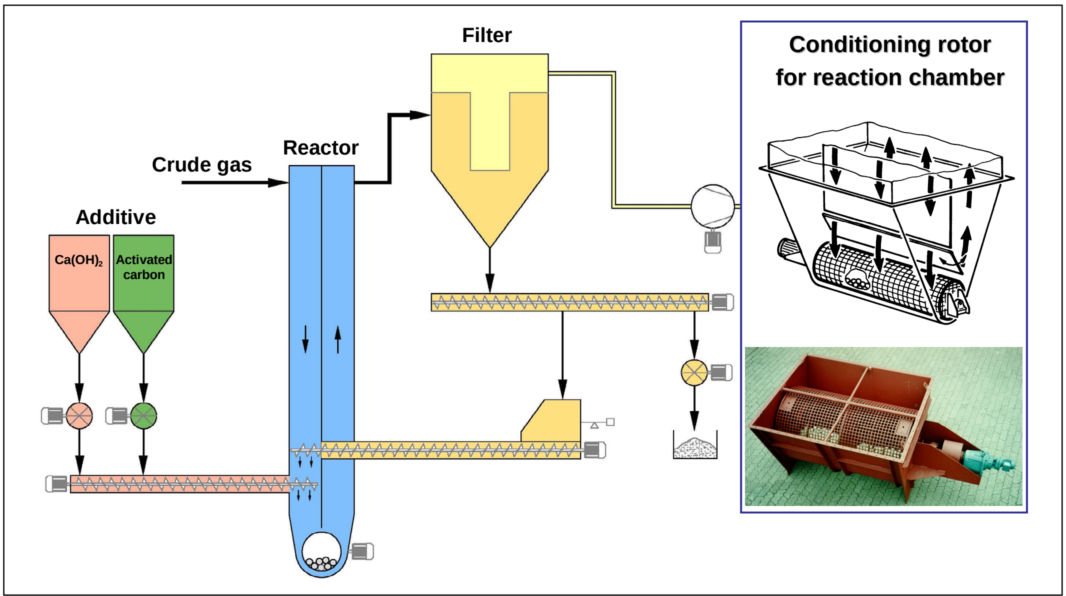
2 Conditioning Rotor - Recycle Process

2.1 Process description

Examinations at a test plant for the cleaning of a part flow from the off-gas of a sinter plant already demonstrated in 1991, that the additional installation of a particle re-circulation and the injection of additive powders, e.g. the qualities $Ca(OH)_2$ or $CaCO_3$, will be necessary to achieve a reliable continuous operation of a fabric filter for the gas cleaning of a sinter plant [1, 2].

A procedure that meets these requirements reliably in continuous operation is the below described Conditioning Rotor – Recycle Process.

The schematic view of the Conditioning Rotor – Recycle Process shown in pic. 2, illustrates a well-proven solution for the reliable re-circulation of even larger re-circulation quantities of particles separated in the filter into an upstream located reactor.



Pic. 2: Schematic view of Conditioning Rotor – Recycle Process

The conditioning rotor is a hollow cylinder, manufactured of a perforated plate with openings of approx. 30 x 30 mm. Up to 5% of its volume is filled with balls made of heat- and wear-resistant ceramics. The rotor is continuously driven by means of a geared motor with a speed of approx. 1 rpm. The rotation causes the balls to move relative to each other and to the perforated shell. The rotor is located in the lower reaction chamber elbow upstream filter, passed through by the crude gas.

The main functions of a conditioning rotor are:

- prevention of particle deposits when reversing a particle-laden crude gas flow
- achievement of a homogeneous distribution of re-circulated particles in the crude gas flow even in case of a high particle concentration (e.g. up to several 100 g/m³)
- disintegration of larger particle agglomerates

Prior to their discharge, the particles separated in the filter are frequently reintroduced into the reactor by means of a conveying screw. The particle recycle rate is adjustable via the speed of screw conveyor and can be controlled on request depending on the current crude gas volume.
Compared to alternative, e.g. pneumatically working re-circulation systems, the Conditioning Rotor – Recycle Process offers among others the following advantages:

- mechanical particle transport by means of reliable screw conveyors
- discharge or possible interim storage of the recycled particulate is not necessary
- a homogeneous distribution of the reintroduced, recycled particulate in the crude gas flow
- high reliability in operation

2.2 Utilisation of Conditioning Rotor – Recycle Process for the separation of dioxins/ furans

For the separation of gaseous dioxins/furans an additive powder quality with large specific surface is injected into the flue gas flow upstream fabric filter. The dioxins/furans are adsorbed at the additive powder particles and in this manner separated at the filter fabric. A multiple re-circulation of the particles separated in the filter has an advantageous influence on the achievable degrees of separation and/or leads to a reduction in operating costs regarding the additive powder consumption and disposal.
The re-circulation by means of Conditioning Rotor – Recycle Process improves the chances of contact between additive powder and crude gas already during fly phase and in the filter.
In most of the cases activated coke and/or activated carbon with a specific surface of approx. 350 up to > 1,000 m²/g are used as additive powder. Due to the fact that these qualities are carbonaceous additive powders, preventive measures have to be taken to avoid dust explosions and smoulder within the filter. As far as a mixture of inert material (at least 70 weight%) and activated coke (max. 30 weight%) is used, dust explosions can be excluded. The additive powder already injected for the particle separation and for the protection of filter serves as inert material.
In addition to the separation of dioxins/furans, the injection of AC allows at the same time a reduction in Hg emissions.

2.3 Utilisation of Conditioning Rotor – Recycle Process for the separation of acid crude gas components, such as HF, HCl, SO_x

For the separation of acid crude gas components commercially available hydrated lime $Ca(OH)_2$ with a specific surface of approx. 15 up to 20 m²/g is normally injected into the gas flow upstream filter. The reaction equations as well as the injection and remainder quantities at an additive powder utilisation of 100% are shown in table 1. In order to achieve the reliable compliance with the requested emission levels for the clean gas in the practice, the additive powder has to be injected above stoichiometry (normally 1.5 – 3fold referring to separated quantity).

Equations of reaction	$Ca(OH)_2$ - injection quantity related to crude gas at 100% stoichiometric (i=1)	Resulting residual particle quantity (with crystal water content according to experience) related to crude gas
$2HF + Ca(OH)_2 \rightarrow CaF_2 + 2H_2O$	1,85 kg/kg	1,95 kg/kg
$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$	1,01 kg/kg	2,02 kg/kg
$SO_3 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O$	0,93 kg/kg	2,15 kg/kg
$SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O$	1,16 kg/kg	2,02 kg/kg

Table 1: Reaction equations for $Ca(OH)_2$

It is provable that especially in case of high additive powder recycle rates, the Conditioning Rotor – Recycle Process will lead to a clear improvement of the degree of separation for acid crude gas components and/or to a reduction in the additive powder injection quantity.

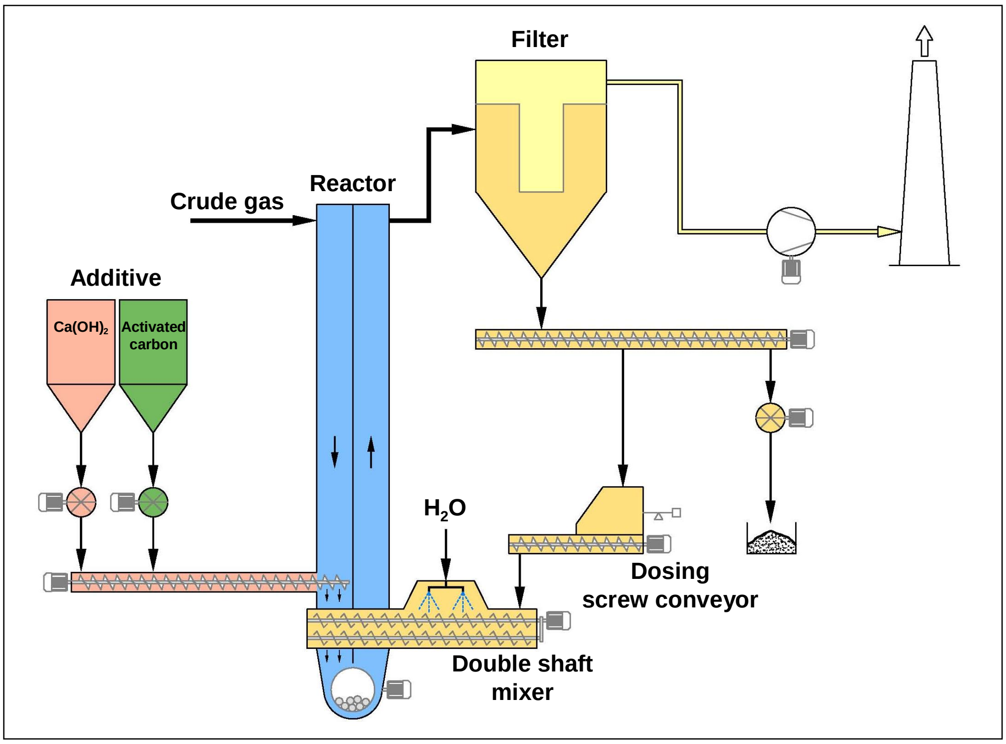
- The residence time of additive particles in the system is increased
- In the reactor upstream filter a higher additive particle density is formed (resulting reaction time in reactor up to > 2 sec.)
- Achievement of a frequent, spatial re-orientation of the re-circulated particulate with re-deposition of the filter cake on the filter fabric.

Regarding the temperature range of 100°C and 220°C which is typical for fabric filters, the following order of reaction results for the reaction rate of the separate crude gas components and the $Ca(OH)_2$:

$$SO_3 > HF > HCl \ >>> \ SO_2$$

The separation of SO_3, HF and HCl does not present any problem in the usual temperature range for sinter plants. However, satisfying degrees of separation for SO_2 with a good additive powder efficiency can only be achieved if the water steam partial pressure is at least in times near to the saturation steam pressure in direct near of the recycled particulate. This will be achieved when using the conditioned dry sorption by means of Conditioning Rotor – Recycle Process (pic. 3). In this procedure, the recycled particles are wetted prior to re-injection into the reactor. The humidification causes an increase in water steam content at the surface of additive

powder particles, thus improving the reactivity compared to the acid crude gas components.
The application of this process variant allows degrees of separation for SO_2 as well as for all other acid crude gas components of up to > 90%.



Pic. 3: Conditioning Rotor – Recycle Process with particle conditioning

3 Use of alternative additive qualities for the separation of acid crude gas components

In principle, sodium bicarbonate, $NaHCO_3$, can also be used as alternative to $Ca(OH)_2$ for the separation of acid crude gas components. After injection of this additive powder quality into the gas flow with temperatures > 140°C, a thermal activation of the $NaHCO_3$ will take place. The result hereof is high reactive sodium carbonate. Table 2 shows the chemical reaction equations as well as the injection and remainder quantities in case of an additive powder efficiency of 100%. As a general rule, the requested emission limit values can be kept in continuous operation with an above-average stoichiometric factor of 1.2 – 1.5, referred to the separated quantity. A multiple re-circulation of the particles separated in the filter into the gas flow upstream filter may be advantageous. Due to the high reactivity of the additive powder, the process can work without the particle conditioning for the separation of SO_2.

Equations of reaction	$NaHCO_3$ - injection quantity related to crude gas at 100% stoichiometry (i=1)	Resulting residual particle quantity related to crude gas
$HF + NaHCO_3 \rightarrow NaF + H_2O + CO_2$	4,2 kg/kg	2,1 kg/kg
$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$	2,3 kg/kg	1,6 kg/kg
$SO_3 + 2NaHCO_3 \rightarrow Na_2SO_4 + H_2O + 2CO_2$	2,1 kg/kg	1,77 kg/kg
$SO_2 + 2NaHCO_3 \rightarrow Na_2SO_3 + H_2O + 2CO_2$	2,63 kg/kg	2,22 kg/kg

Thermal activation of $NaHCO_3$:

$$2NaHCO_3 \xrightarrow{T \geq 140\ °C} \underbrace{Na_2CO_3}_{\text{high-reactive, porous crystal structure}} + CO_2 + H_2O$$

Tab. 2: Reaction equations for $NaHCO_3$

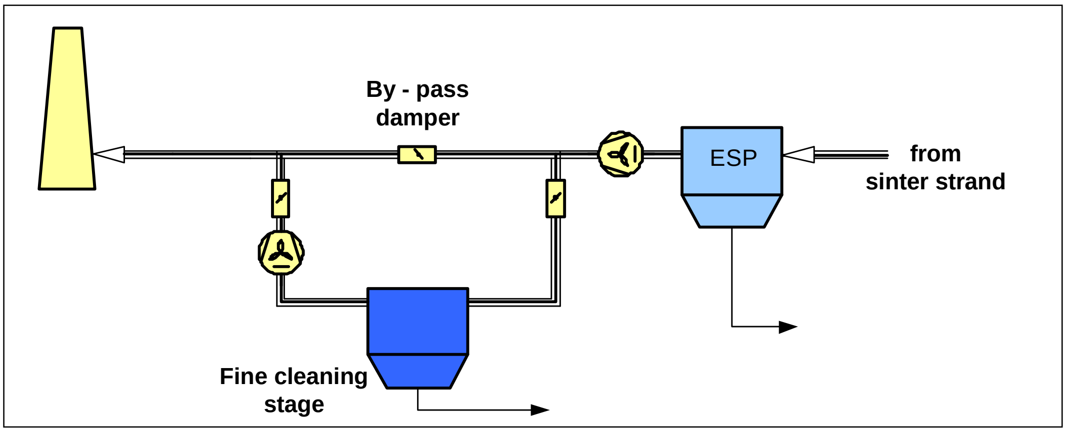
However, this process offers considerable disadvantages:

- Unfavourable mass ratio of additive powder to acid gas component
- Grinding of additive powder prior to injection into the gas flow necessary
- Compared to $Ca(OH)_2$ high specific purchase costs for the additive powder
- Provision with additive powder not assured all over the country
- The gas temperature should be > 140°C.

From the point of view of the author and based on the before-mentioned disadvantages, this process cannot be applied without reservations for the fine cleaning downstream sinter plants.

4 Operating experiences
4.1 Sinter plant ArcelorMittal Bremen
4.1.1 Integration of the fine cleaning stage into sintering plant

In the scope of an increase of plant production in Bremen, the plant was in 1993 equipped with a fine cleaning stage for the reduction in emission of particles, heavy metals as well as dioxins/furans. The additional stage – realised as Conditioning Rotor - Recycle Process without particle conditioning – was installed downstream of main fan of sinter plant (pic. 4).



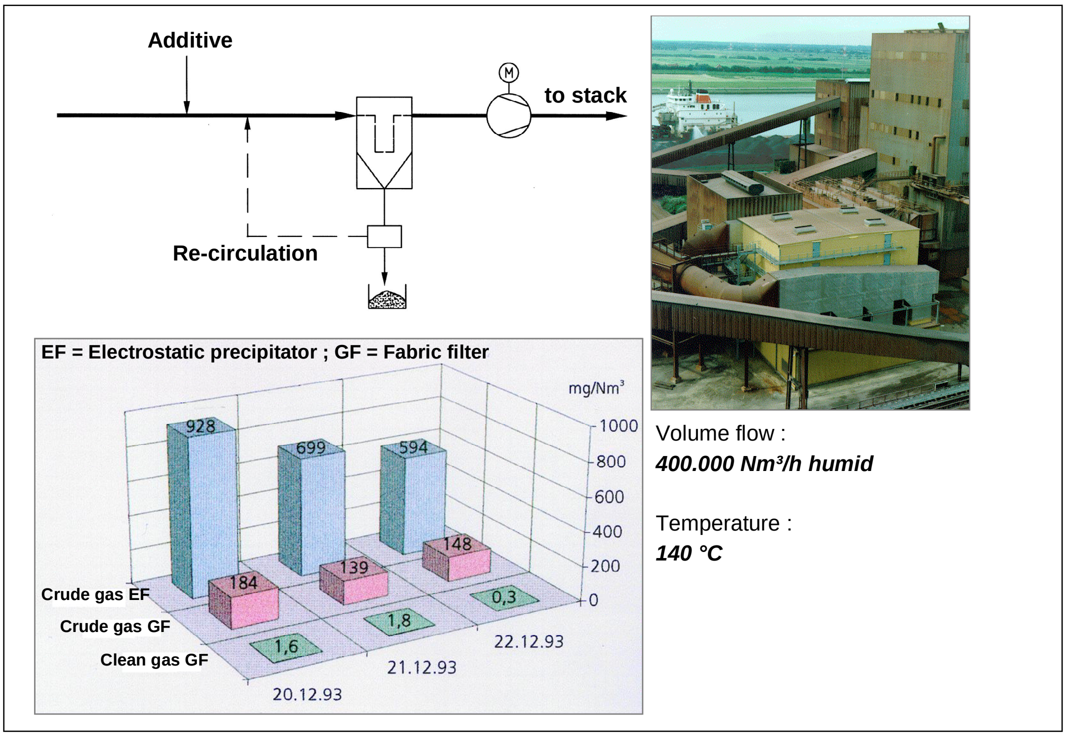
Pic. 4: Integration of fine cleaning stage into overall plant

With regard to the start-up and the shutdown of plant, the authorising body approved the installation of a by-pass around the fine cleaning stage. A by-pass slide valve avoids that during normal operation, untreated gas will directly pass the stack.

Due to the very high pressure of main fan of sinter plant in relation to the fan of fine cleaning stage, measures had to be taken regarding the plant control to avoid in all operating modes that the downstream installed second filter stage will be driven in overpressure.

4.1.2 Operating results related to the emission values

Comprehensive emission measurements have been realised at the plant, collecting not only the clean gas values but at the same time also the crude gas values for different components. Picture 5 shows the efficiency of the particle separation. The reached clean gas values are definitely below the requested limit values and also the degrees of separation for particulate heavy metals show comparatively good values.

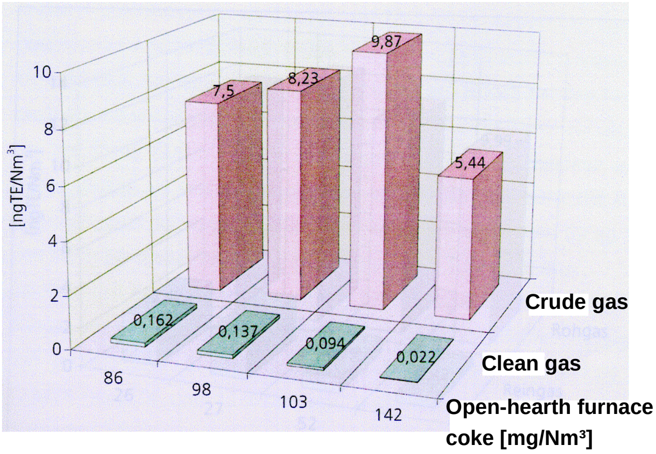


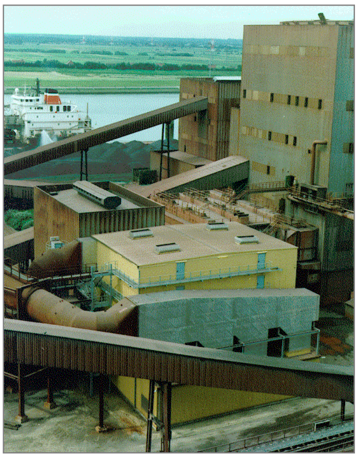
Pic. 5: Simultaneous particle measurement upstream and downstream ESP as well as Downstream fine cleaning stage [3]

Regarding the separation of dioxins/furans, activated coke is injected as additive powder with large specific surface (approx. 300 m²/g). At the same time, $Ca(OH)_2$ is injected in addition as an inert material into the ducting upstream reactor. The tasks of this inert material are:

- reliable avoidance of dust explosions
  (injection ratio AC : $Ca(OH)_2$ > approx. 1 : 3)

- avoidance of corrosion by reducing the acid dew point
- protection of filter fabric against an increase in differential pressure due to the deposit of very fine alkali and/or hydrocarbons





Pic. 6: Measuring results concerning the separation of dioxin/furan [3]

After commissioning of plant, dioxin measurements with different additive powder injection quantities have been realised. (pic. 6).

In practice it turned out that a specific injection quantity of AC of less than 0.08 g/Nm³ will be sufficient for the reliable observance of the requested emission limit value of < 0.4 ng/Nm³.

The separation of acid crude gas components and in this connection especially of SO_2 has not been requested for this plant as the limit value of 500 mg/Nm³ for SO_2 is already observed as a result of primary measures.

4.1.3 Measures for an increase in capacity

In the course of the past years, the operator realised a definitely specific increase in production capacity of sinter strand. As a result of this it became also necessary to increase the throughput of fine cleaning stage. In 2007 another filtration line was installed, thus increasing the volume flow through plant from 400,000 Nm³/h to more than 580,000 Nm³/h. This year tests have been launched at the plant with specially developed filter fabric compositions, in order to try to increase the filtration velocity at constant filter differential pressure and observance of emission limit values. The main changes regarding the needle felt composition are:

- lower specific weight
- higher permeability

First results are expected in the course of this year.

4.1.4 Remainders

The remainders discharged from the filters are redirected to the sinter strand. It could be proven that the dioxins/furans adsorbed at the AC are completely destroyed on the sinter strand. An increase in dioxin/furan crude gas values upstream existing cleaning stage could not be observed. At least a part of the product separated in the ESP will be carried to a landfill, in order to avoid an excessive increase in alkali content in the particle spectrum upstream ESP.

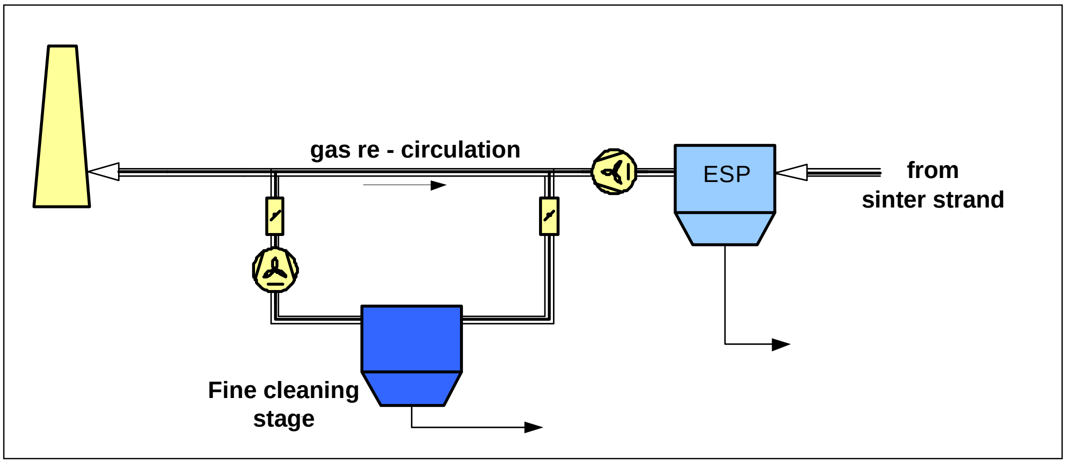
4.2 Sinter plant Voest Alpine Stahl Donawitz

4.2.1 Integration of the fine cleaning stage into sintering plant

In 2002 the second fine cleaning stage downstream sinter plant, realised as Conditioning Rotor – Recycle Process with particle conditioning, was put in operation at Voest Alpine Stahl Donawitz. The special feature of this sinter plant is the use of ores with high alkali content.

Compared to the variant described in item 4.1, this plant was realised with a fine cleaning stage between main fan of sinter plant and stack with gas re-circulation duct (pic. 7).

Due to the fact that no butterfly valves etc. are installed in the re-circulation duct, it must be ensured by operation of the bag filter system that no untreated off-gas will pass the stack. This is realised by operating the bag filter fans with slightly higher flow rate than the sinter strand main fan. Therefore it is ensured that the gas flow in the re-circulation duct goes in the right direction.



Pic. 7: Integration of fine cleaning stage into overall plant

This solution guarantees that the operation of the sinter plant and the bag filter are kept as independent as possible. Of course, the disadvantages of the gas re-circulation duct are the approx. 5% higher total gas volume, the necessity to install a second fan downstream bag filter and the fact that the main fan is not protected against wear caused by dust. But the advantages such as

- extremely high flexibility with different operation conditions like start-up and shutdown of the sintering plant
- nearly atmospheric pressure at the take-over point (low expenditure regarding the reinforcement of component parts as well as smaller filter surface)
- no by-pass valves necessary
- on line- maintenance without any problems possible
- simple integration into existing systems

outweigh the disadvantages clearly.

4.2.2 Operating results

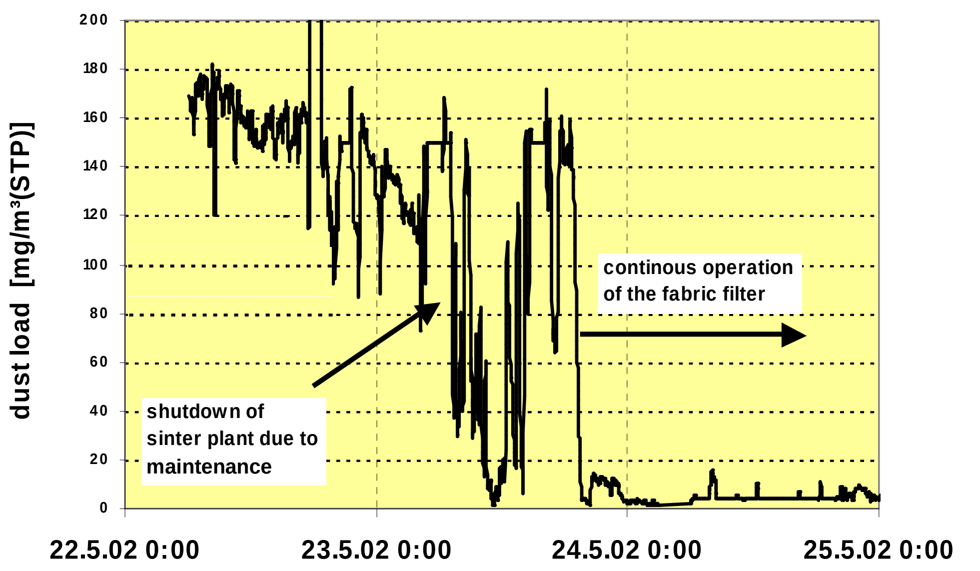
The operator requested the reduction in emissions of particles, heavy metals, dioxins/furans as well as of the acid crude gas HF, HCl and SO_2. Emission limit values and actually reached emission values are comparatively shown in pic. 8.

		restrictions	measured values
Dust	mg/m³ STP.	50	1.5
SO_2	mg/m³ STP.	500	450
NOx	mg/m³ STP.	400	260
HCl	mg/m³ STP.	30	1.6
HF	mg/m³ STP.	5	0.2
PCDD/F	ng/m³ STP.	0.4	< 0.4

Source : VASD

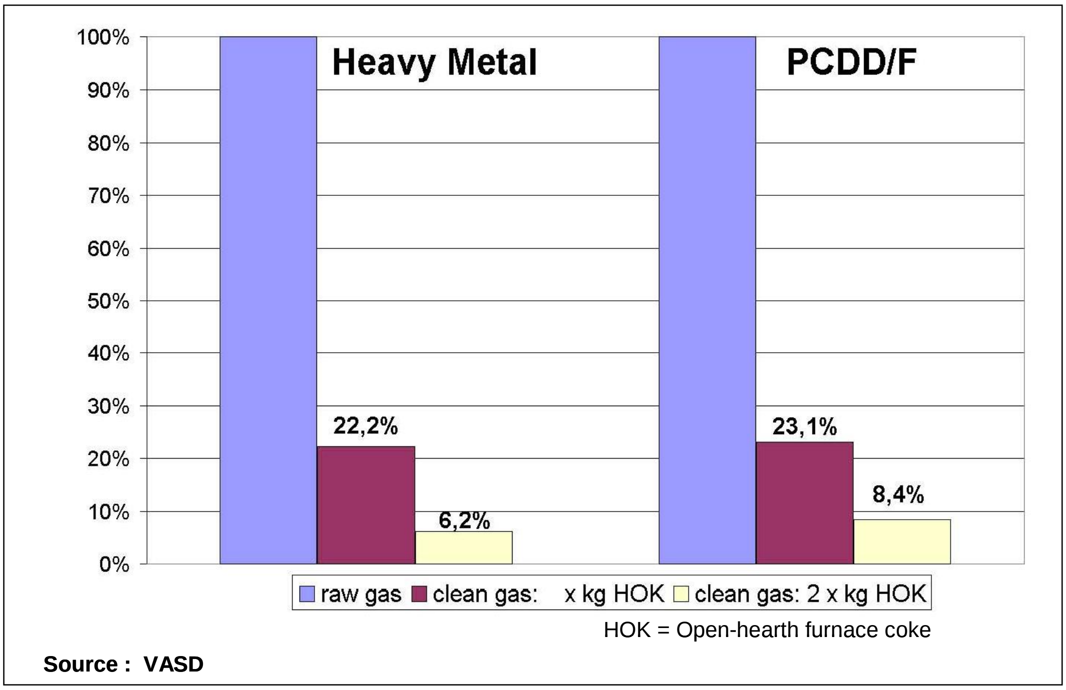
Pic. 8: Examples for operating results at plant Voest Alpine Stahl Donawitz

Picture 9 additionally illustrates impressively the effectiveness of the fine cleaning stage for the separation of particles by means of the trend curves for the particle measurements at stack during the initial commissioning of plant.



Pic. 9: Dust emissions in stack with bag

With regard to the separation of dioxins/furans and mercury as well as mercury compounds, activated coke with a specific surface of approx. 300 m²/gis used as additive powder. As shown in pic. 10, the achievable degree of separation depends among other things on the additive powder injection quantity [3]. In order to observe the requested limit value for dioxins/furans in continuous operation of 0.4 ng/Nm³, a specific injection quantity of < 0.07 g/Nm³ will be necessary.

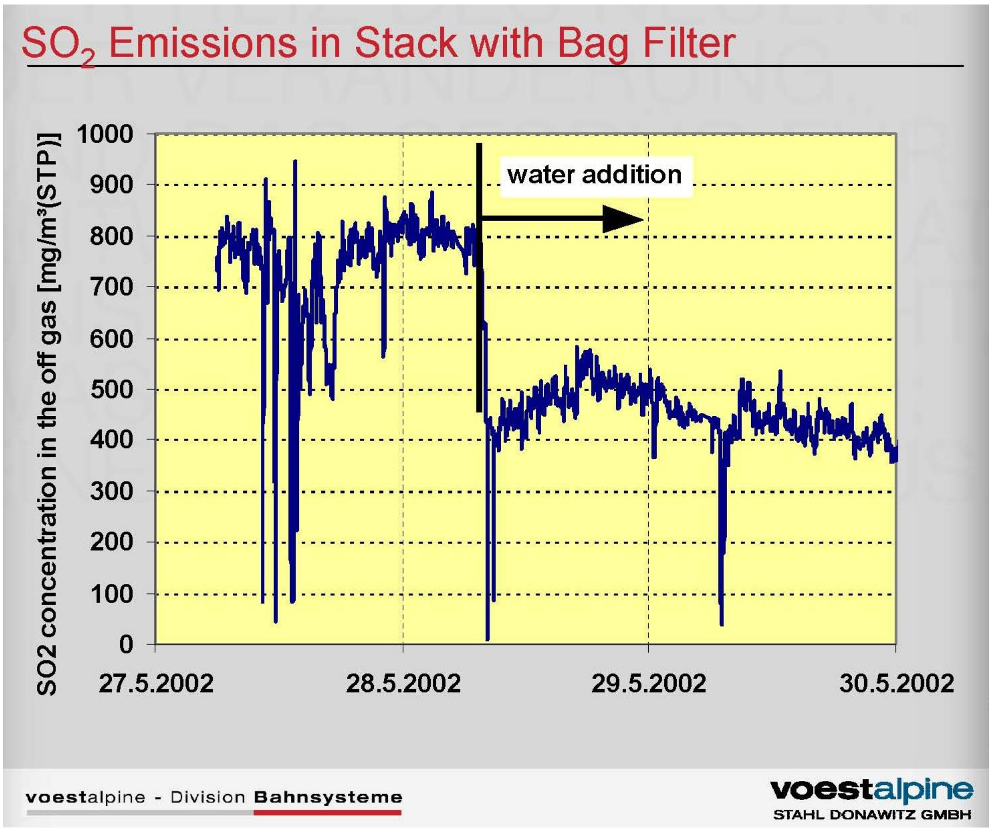


Pic. 10: Removal of dioxins and mercury [4]

Due to the fact that also the separation of SO_2 had been requested for this application, the fine cleaning stage had been realised as Conditioning Rotor – Recycle Process with particle conditioning.

Picture 11 clearly demonstrates the influence of particle conditioning. Prior to water injection into the humidifying mixer and in spite of a particle re-circulation rate of approx. 150 g/Nm³ the achieved degrees of separation only were in a range of 5 up to max. 10%. Only after moistening of the re-circulated particulate with an at the same time acceptable additive powder consumption the requested emission levels of < 500 mg/Nm³ dry could reliably be observed in continuous operation.

The reason for the successful separation of SO_2 with the Conditioning Rotor- Recycle Process with particle conditioning is that the required reacting parties – SO_2 – molecule, additive powder particles and water – are directly brought together in the reactor. During injection into the reactor the water is already adsorbed at the additive powder and not injected separately as e. g. in case of other procedures. Another advantage of this process is that high degrees of separation can be achieved even in case of comparatively low gas temperatures as e. g. 110° C.



Source : VASD

Pic. 11: SO_2 concentration with and without particle conditioning Voest Alpine Stahl Donawitz

4.2.3 Filter fabric quality

Starting with the first filter bag exchange at plant approx. four years after commissioning, test bags with different fibre and support scrim qualities as well as different needle felt compositions have been installed at plant with the objective to extend the filter fabric service life. In addition to the so far installed needle felt quality 100% Aramid, bags of the quality 100% PPS have been mounted. With regard to the needle felt composition, variations concerning the support scrim have been realised. After several years of testing, the first positive results are reached.

4.2.4 Remainders

The operator of plant in Donawitz tested in practice different methods concerning the integration of remainder from the filtration plant in the production process:

a) Re-circulation to the sinter strand

A continuous injection of the product discharged from the filter into the sintering raw mixture will not be possible as there is no sufficient sink for SO_2 and also for chlorides available.

b) Injection into blast furnace

Also this method of reuse had to be cancelled after short time of testing. The reason was the high chloride and heavy metal content in the scrubbing water of the gas treatment system downstream blast furnace. However, when assessing this result, the special features of the used iron ores with very high portions of alkali chloride and heavy metals compared to other ores has to be taken in consideration.

Today the remainder of the fine cleaning stage is stored in a disposal site. Prior to storage and based on an especially developed method, the filter dust is mixed with different other remainders, which are produced in the integrated steel works and which cannot be reintroduced in the production process. By this, the remainder is converted into an inert material.

5 Summarising assessment

Experiences gathered from the operation of several fine cleaning stages - realised as Conditioning Rotor – Recycle Process - installed downstream sinter strands, confirm the high separation efficiency of this technology as well as its reliability in continuous operation.

- The today requested emission limit values for particles and heavy metals are reliably observed
- The high particle re-circulation rate grants a reliable dioxin/furan separation with low dosing quantities of activated coke
- The humidifying mixer integrated in the particle re-circulation cycle allows degrees of separation for SO_2 of > 80% with optimised additive powder consumption

The plant requirements regarding the crude gas and clean gas values as well as the resulting degrees of separation depend on the application in question. The before-mentioned all-purpose process, described by means of practical examples, shows that it can be adapted to the corresponding application.

Independent of the chosen process, there is a general need for optimisation regarding the recovery of remainders, especially for applications with requested SO_2 separation. In this case, the re-circulation of the product discharged from the filter into the sintering mixture will not be possible. From the author's point of view, further examinations should be realised, aiming at an injection of discharged product into the blast furnace in order to avoid landfilling.

References

[1] Best available techniques reference document on the production of iron and steel
Integrated Pollution Prevention and Control (IPPC)
European Commission
December 2001
[2] Reduction in emission levels downstream sinter plants with LÜHR conditioning rotor-recycle process for particles (alkalines), dioxins/furans, SOx, heavy metals.
Margraf, R. and Pottie, P.
3rd International Meeting on Ironmaking
Sao Luis, BR, 22.09.2008
[3] Maßnahmen zur Verbesserung der Entstaubung einer Eisenerzsinteranlage mit nachfolgenden Untersuchungen zur Minderung der PCDD/PCDF-Emissionen
Measures regarding the optimisation of a de-dusting plant for an iron ore sinter plant with subsequent examinations regarding the reduction in PCDD/PCDF emissions.
Weiss, Wolfram
Abschlussbericht im Auftrag des Umweltbundesamtes
Final report by the order of Federal Environment Agency
December 1998
[4] Waste gas cleaning by bag filter at the sintering strand of voestalpine Stahl Donawitz
Habermann, Arno und Zirngast, Johann
SATEC 10, China

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