CHALLENGES IN RENDERING CO-RICH GAS FROM SUBMERGED ARC FURNACES SUFFICIENTLY CLEAN FOR CO-GENERATION APPLICATION

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ABSTRACT

This paper examines the challenges in the off-gas cleaning in the SAF ferroalloy production and introduces a solution to render the gas stream sufficiently clean to be utilized for energy generation from the CO-rich gas instead of wasting the energy by flaring in the furnace stack. The micro size and ultrafine particles and volatiles like tar components are difficult to collect by means of any wet scrubbing method. The latest approach is a cassette-type ceramic filter that facilitates the removal of particles that pass through the furnace scrubbers. Tar components are hydrophobic and therefore difficult to collect in a wet scrubber and additional measures are required to produce sufficiently clean gas for power generating engines. The mentioned filter is ideally suited to power generation engines. In combination with the filter, fine material is used to capture tar and condensate water from the furnace process gas to prevent filter elements from blocking.

KEYWORDS: *Reductants, gas cleaning, gas filter, power generation.*

GENERAL

In order to make electricity from the ferroalloy furnace gas most efficiently, the gas must be clean. If CO-gas is used to make electricity in special engines, the gas has to be very clean < 5 mg/Nm^3. In gas engines the efficiency can reach 37 % from the thermal power of the furnace gas. In gas combustion steam process utilizing thermal power and to make steam, efficiency remains at about 30 %.

The Polycyclic aromatic hydrocarbons from reductants are not easy to collect from gas in wet scrubbing used in ferroalloy processes. These components are hydrophobic and easily start blocking any filter before power generation unit.

FERROALLOY PROCESS FURNACE GAS

In ferroalloy production with closed submerged arc furnace operation, CO rich gas is produced, like in Outotec ferrochrome process with preheating (figure 1). In ferrochrome process with preheating, the furnace off-gas CO-content can be as high as 85-87 %.

There is a great potential to utilize furnaces CO-gas and produce electricity, which is becoming more and more expensive around the world. There are different ways to generate energy from CO-gas like generating heat or to use it as fuel in special power engines or in gas combustion boilers.

In many cases furnace CO-gas is utilized for preheating of the feed charge and then as a fuel in pelletising plant. There is still an excessive amount of CO-gas available to generate electricity from CO-gas. The reduction develop about 650–750 Nm^3/t FeCr of CO-gas. Preheating and pelletising plant normally use about 30 % from produced CO-gas. Heat value of the furnace CO-gas is typically about 2.8-3.2 kW/Nm^3.

GAS CLEANING

Off-gas from the closed SAF is normally cleaned with wet scrubbers. In wet scrubbing, the challenge is to get micro and ultra fine particles to the gas cleaning water. Other challenge is the hydrocarbons from reductants used in SAF. Wet scrubbing is based on wetting of the dust particles. Polycyclic aromatic hydrocarbons (PAH) are hydrophobic and pass through wet scrubber easily. Increasing usage of anthracite will bring more tar and gas cleaning and filtering of the CO-gas becomes even more challenging.

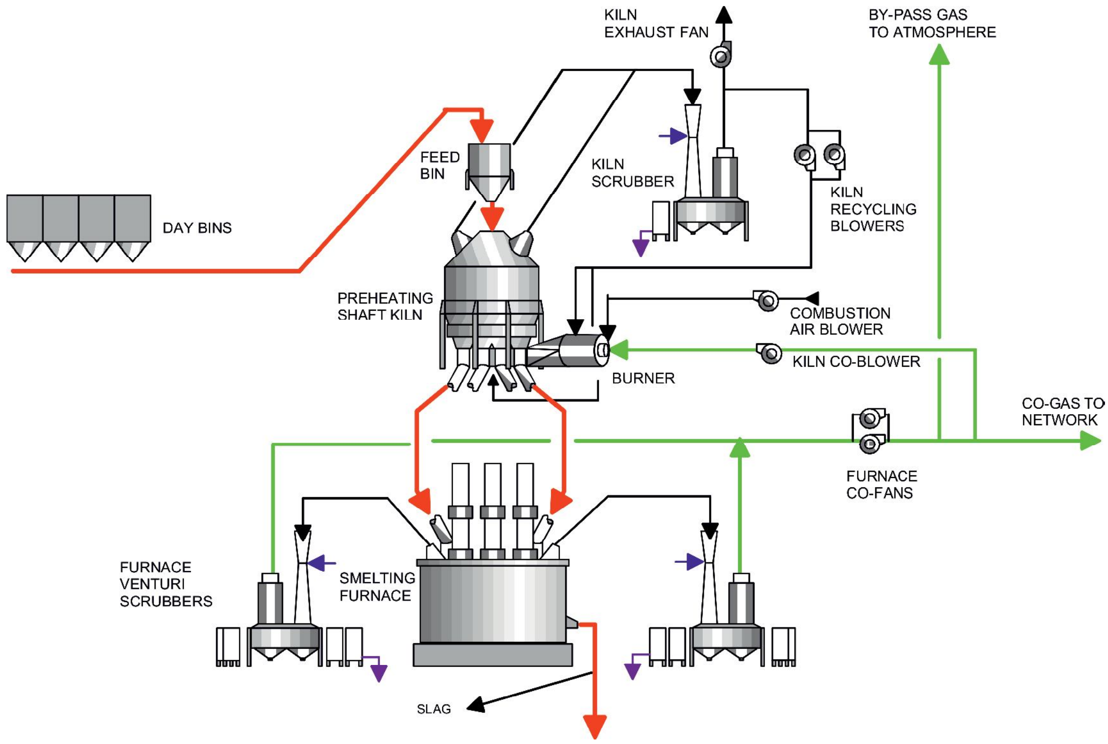

Figure 1: Outotec CO-gas handling

Reported furnace dust is about 30-40 kg/tonne of FeCr. Dust from closed ferrochrome furnace has following components:

- Cr_{tot} 1–10 %
- Fe_{tot} 1–6 %
- C 3–10 %
- MgO 20–40 %
- SiO_2 15–30 %
- Al_2O_3 1–10 %
- CaO 0–5 %
- S 0.5–2 %
- Zn 1–10 %
- Na_2O 2–4 %
- K_2O 2–5 %

For closed furnace gas cleaning there are two dominating gas cleaning options, one is with high water flow but low 6 bar pressure and other one with lower water amount, but high 30 bar water pressure (figure 2).

In high pressure venturi scrubber, the water pressure provides the scrubber and gas line towards the process fan to be pressurized (1-5 kPa). This prevents air to penetrate in to gas stream and to make explosive gas mixture.

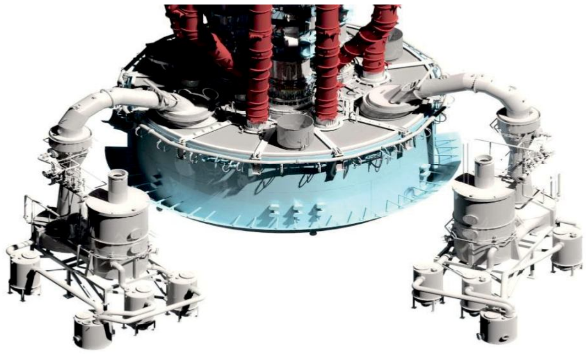

Figure 2: High pressure venturi scrubber for furnace gas cleaning

From ferroalloy furnace the gas has significant amount of micro and ultra fine particles, which are difficult to take out. Smaller the particle, more energy is needed to remove them from the gas to the gas cleaning water. Tar and PAH components in the furnace gas also capture particles from the gas and make particles hydrophobic and don't get wetted and pass the scrubber in the gas stream.

To get gas to the quality of the level for power generating special engines, the target is to get gas cleaner than 5 mg/Nm^3. To achieve this target Outotec has developed and patented new concept utilizing a cassette-type CO gas filter (figure 3, 4) which enables the removal of the smallest particles that pass through scrubbers. The solids in gas after the special filter have been analyzed to be about 1 mg/Nm^3 or less. The gas is blown into the CO-gas filter with tar/PAH capturing media particles and the gas flow is uniformly distributed between all the filter elements. The gas flows through the filter elements and collected dust is dropped down with nitrogen pulse. Filter unit works like bag filter and nitrogen is used to purge particles out from filter elements. These filter elements have porous structure and tar and PAH components can block elements. To prevent elements from blocking, for example coke dust is injected in to the incoming gas stream. In coke dust injection unit, nitrogen is used to keep it safe and CO does not reach too high values.

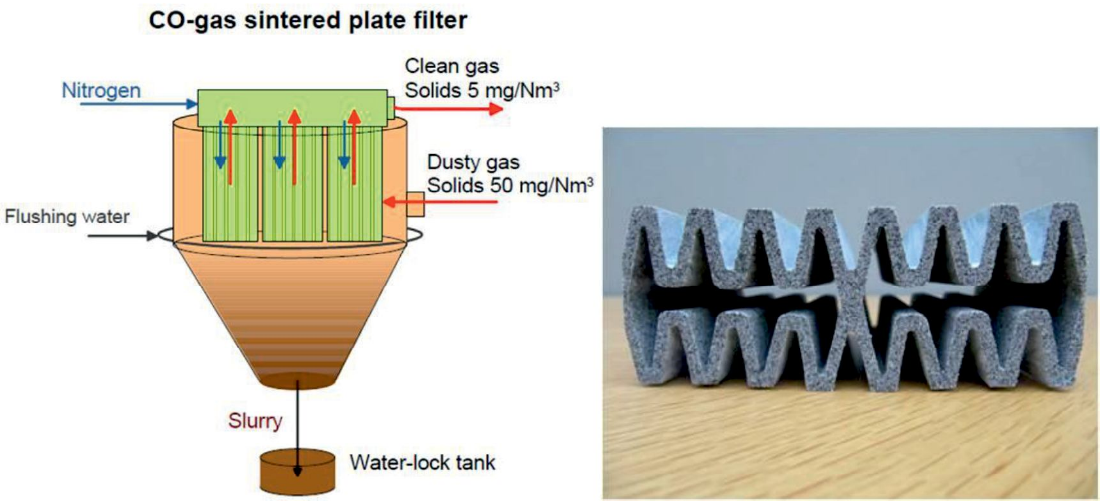

Figure 3: A cassette-type filter unit and type of filter element used in the gas filter

In table 1 is described how different technologies are able to collect fine particles and in table 2 two measured sieve analysis of particle sizes from scrubber dust.

The patented CO-gas cassette filter is divided into three main parts; CO-gas filter chamber, filter elements and nitrogen pulse cleaning. The chamber of the CO-gas Filter consists of two inlets and outlets for the process gas, explosion hatches, ventilation connections, cleaning sprayers and slurry drain unit.

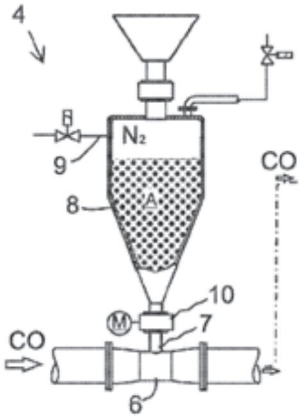

Figure 4: System for removing solid particles and tar component from carbon monoxide gas

The differential pressure of the filter is measured and is normally 3-5 kPa. If the pressure difference increases, this indicates the filtering elements are clogging. The pressure difference alteration during the operation indicates how successful the gas cleaning is and how well the tar removing media material injection is functioning. If the pressure difference exceeds the high-high value, the filter off-sequence comes into action.

Table 1: Gas cleaning efficiencies of different techniques

Equipment	Collection efficiency (%) at following sizes:				
	50 μm	5 μm	1 μm	High temperature	Relative cost*
Inertial collector	95	16	3	yes	1
Medium efficiency cyclone	94	27	8	yes	3
Low resistance cellular cyclone	98	42	13	yes	2
High-efficiency cyclone	96	73	27	yes	4
Impingement scrubber	98	83	38	no	7
Self-induced spray deduster	100	93	40	no	5
Void spray tower	99	94	55	no	11
Fluidised bed scrubber	>99	99	60	no	8
Irrigated target scrubber	100	97	80	no	6
Electrostatic precipitator	>99	99	86	yes	9
Irrigated electrostatic precipitator	>99	98	92	no	13
Flooded-disc scrubber - low energy	100	99	96	no	10
Flooded-disc scrubber - medium energy	100	>99	97	no	15
Venturi scrubber - medium energy	100	>99	97	no	14
High efficiency electrostatic precipitator	100	>99	98	yes	16
Venturi scrubber - high energy	100	>99	98	no	18
Shaker type fabric filter	>99	>99	99	no	12
Reverse jet fabric filter	100	>99	99	no	17
Ceramic filter elements	100	>99	>99	yes	18

*relative cost per 1000 m^3 of gas treated - the lower value the better

For example coke dust is injected to the CO-gas duct. Coke dust has a large surface area, and it has an ability to absorb tar on the surface of the particles. Thus the coke particles remove tar from CO-gas. Thereafter the filtration of CO-gas purifies the gas from solid particles and tar coated coke particles. The equipment contains coke injection device with coke bin, screw feeder, and the duct with a venturi part and valves.

Table 2: Two samples from scrubber particles

m	Passing the sieve [%]	
74	43.9	25.62
53	37.76	21.51
44	33.26	18.98
37	29.29	16.96
20	19.11	11.88
10	12.3	7.67
5	6.97	4.61
2	3.09	2.62
1.8	2.87	2.38
1.5	2.48	1.71
1.2	2.1	0.96
1	1.06	0

Dirty CO-gas with tar components flows from the left to the narrowing of the duct, which increases the speed of the gas. At the same time the solid material i.e. coke dust spreads uniformly into the gas flow.

The coke dust disperses onto the broaden gas as CO-gas leaves the narrow part of the. It is very important that the coke dust spreads to the whole cross-section of the duct allowing solid coke particles and tar components get into contact with each other.

The filter unit consumes nitrogen to keep filter elements clean. Nitrogen is used as pulses and the effect on the CO content of the gas is not significant. The amount is 70 Nm^3/h for 10 000 Nm^3/h filter unit as maximum usage. Filtering area used for gas cleaning is about 20-25 cubic meters per cubic meter of gas. Consumption of coke dust (figure 4) is about 6-15 kg/h.

POWER GENERATION

In power generation with gas engines the gas holder tank after gas cleaning from furnace is an advantage. With gas holder tank gas supply is more stable and availability of the engines can be maximized. In power generation engines there is gas filter before the engine. This filter is expensive and change is time consuming and therefore gas should be cleaned well before engines themselves.

Power generating engines can be flexible for fuels but different compositions may require adjusting to engines. Emissions are low and the emissions are low etc $NOx<500$ mg/Nm^3, $SOx<1$ mg/Nm^3.

In figure 5 block diagram is shown how CO-holder tank improves utilization of CO gas. Also in CO consumption possible pelletising plant CO consumption is taken into account in normal operation. Separate pressure increasing fan is used to achieve pressure about 25-35 kPa.

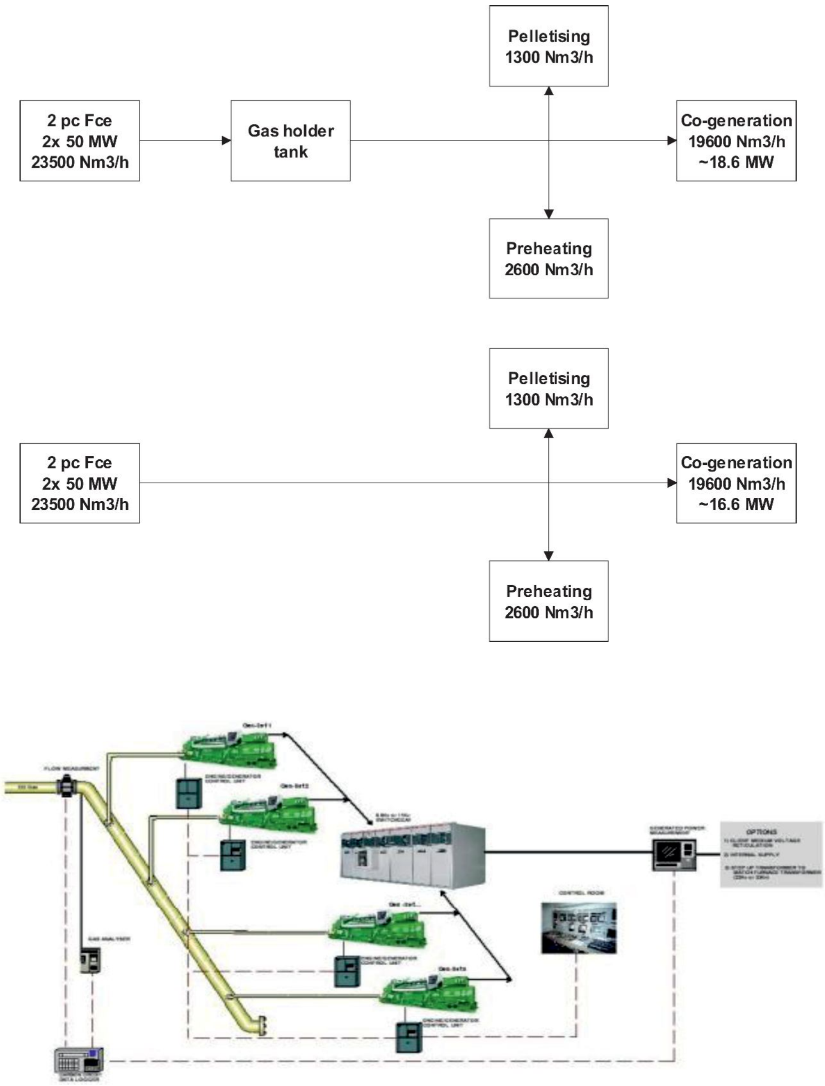

Figure 5: Power generation block diagram

SUMMARY

In Ferroalloy production with rising price of electricity, the generation of electricity from furnace CO gas has become more and more attractive opportunity to utilize available source of energy. Effective use of furnace gas in electricity production requires high quality requirements for the gas. The usage of reductants with high volatiles gives challenges to gas cleaning and gas handling systems. CO_2 trade and more and more environmental awareness increase utilization of furnace gases.

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