Solutions for dusts and sludges from the BOF process

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During the production of 130 million t of crude steel (EU 25) by the BOF process approximately 1.7 million t of BOF dust and 1.3 million t of BOF sludge are generated. Although these residues contain noteable amounts of iron, their use in integrated steelworks is often limited due to environmental problems, negative impacts on productivity and problems during handling. The DK process has shown for now more than 20 years that there is a sustainable solution for treating these residues in an industrial scale.

1
Blast furnace plant of DK Recycling und Roheisen GmbH

The production of 44.5 million t of crude steel in Germany in 2005 was accompanied by the involuntary production of approximately 1.4 million t of waste oxides [1; 2]. Sinter strands within integrated steel mills can and do recycle some of these waste oxides. In practice trace elements like zinc often limit the amounts that can be recycled. Moreover increased amounts of waste oxides on the sinter strand may raise the emissions of dust, heavy metals, dioxins and furans [3]. For this reason, the waste oxides have been dumped in the past. Because of the increased pressure from European and national legislation, dumping becomes more and more difficult and expensive in Europe. Some steelworks have been forced by the authorities to stop dumping waste oxides. Therefore, various processes have been invented to recycle these iron oxides, which often contain valuable iron units. Very few of the

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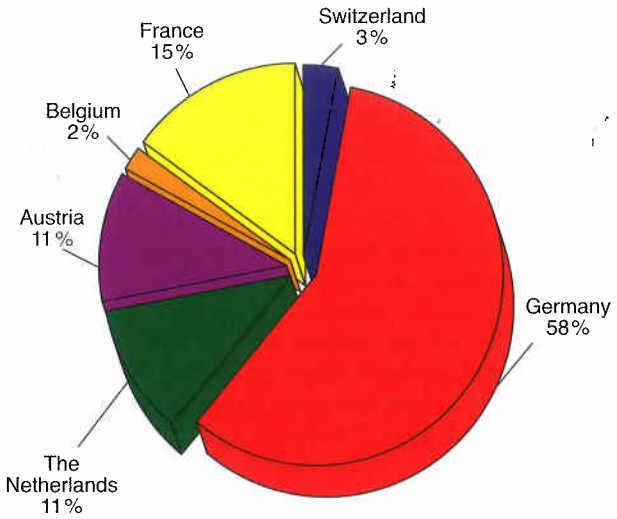
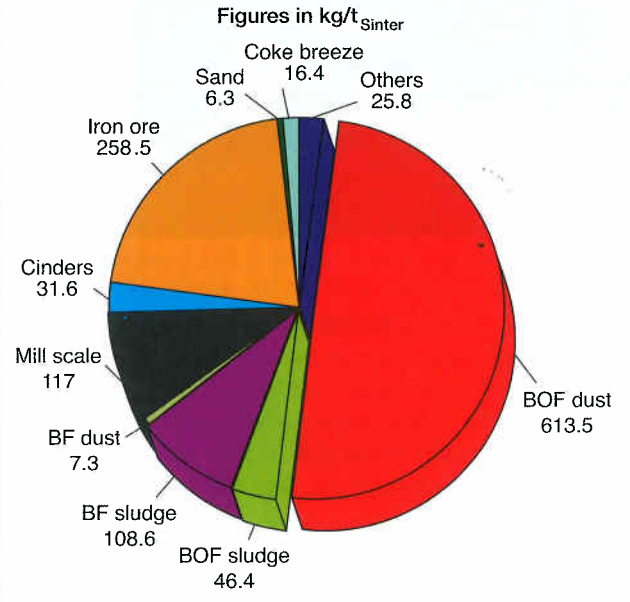


2
Origin of waste materials

	% H_2O	% Fe	% Zn	% Na_2O	% K_2O
BOF dust 1	10.0	65.0	0.9	0.43	0.24
BOF dust 2	1.5	51.1	2.2	0.84	0.39
BOF dust 3	0.0	44.2	11.9	0.31	0.27
BOF sludge 1	21.1	44.8	1.3	0.14	0.10
BOF sludge 2	20.0	48.0	1.1	0.12	0.14

3
Analysis of different BOF dusts and sludges



4
Raw material mix for the sinter plant

processes ever came to the stage of a fully developed production process coping with noteable quantities of residues processed.

Company history

DK Recycling und Roheisen GmbH, figure 1, was founded in 1876 as Duisburger Kupferhütte by ten chemical companies with the aim to buy pyrite (iron sulphide) on the world market. After the roasting of the pyrite in the production of sulphuric acid, the resulting cinders were processed at the Duisburger Kupferhütte. They were mainly iron but also contained small amounts of non-ferrous and precious metals. Production included copper, copper compounds, zinc, zinc oxide, lead, cadmium, ferrocobalt, sodium sulphate and a special, pearlitic stabilising pig iron. In 1983, the processing of cinders came to an end because the chemical industry switched from using pyrite to elemental sulphur for the production of sulphuric acid.

The non-ferrous production was closed but the production of foundry pig iron in the blast furnace continued. The raw material for the pig iron production was switched from pyrite to steel mills residues. Since that time, DK belongs to a Trust established under English law. Beneficiaries of the trust are the employees. The maintenance and securing of workplaces is therefore the primary objective of the Trust. Besides that, the trustees see their further duties in the payment of pensions to DK's numerous pensioners as well as the solving of the outstanding environmental issues.

Today DK processes with 270 employees about 430 000 t/a of different dusts and sludges using a sinter plant to transform the waste oxides into a form that meets the requirements for processing in a blast furnace. The 250 000 t/a of hematite pig iron from the blast furnace, casted on a pigging machine, are sold to the foundry industry in Germany and Europe. With those figures DK is the world's biggest recycling company for steel mills waste oxides. On the other hand, DK is the only producer of hematite pig iron in Central Europe, which gives a strong position in this market.

Raw materials

Today, DK processes about 430 000 t of iron bearing waste materials, which are BOF dust and sludge, BF dust and sludge, mill scale, cinders, cupola dusts, blasting materials and waste water sludges.

Small amounts of iron ore is used for ensuring a stable sinter analysis as well as an improved permeability of the raw material mix during sintering.

Steel mills waste oxides are an European issue. Today DK recycles residues of eight steelworks from six different countries, figure 2.

Successful recycling processes should be able to meet the following demands:

- easy, robust and flexible plant technology to react on variations in raw materials
- reasonable relation between products and by-products
- high operational efficiency
- metallurgical flexibility to run the process in a stable manner despite elements and compounds with a high "disturbance value" (Zn, K_2O, Na_2O etc.)
- capability to cope with emission problems (SO_2, F, Cl, dioxins etc.).

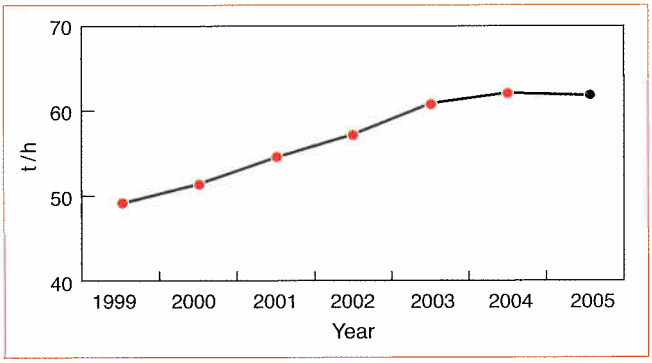
There are great differences in the chemical and physical properties of BOF dust, depending on the operational practice in the BOF shop, the raw materials and the gas cleaning equipment, as can be seen from figure 3.

The physical condition may vary from extremely dry and dusty over briquetted to muddy and spadeable. All these different conditions can be handled in the premixing plant leading to a raw material mix which can be handled in bins.

BOF dusts and sludges play an important role in the raw material mix of DK since they account for approximately 660 kg/t_{sinter}, figure 4. Nevertheless, the process is flexible enough to react on quantitative and qualitative variations respectively, meaning that the share of BOF dust/sludge in the mix can vary between 0 and 1 000 kg/t_{sinter}.

Year of construction	1982
Manufacturer	Lurgi
Nominal capacity	400 000 t/a
Strand length	40 m
Strand width	2 m
Effective sintering suction area	60 m^2
Number of suction boxes	16
Production	1 350 t/d
Waste gas cleaning	1. Electrostatic precipitator
	2. $Ca(OH)_2$ and lignite coke injection
	3. Bag filter

5
Technical data of the sinter plant



6
Development of sinter production

		BF 3	BF 4
Year of construction		1974	1959
Last reline		2006	1998
Number of tuyères		12	9
Hearth diameter	m	5.5	4.5
Blast volume	m^3/h	55 000	50 000
Injection		Oil	No
Working volume	m^3	580	460
Nominal capacity	t/24 h	700	500
Status		Producing	Idle

7
Technical data of the blast furnaces

Sintering process

The agglomeration of the fine oxides is done on a conventional sinter strand with cooling on the strand, figure 5. The sinter process starts with the preparation of the raw materials feed. The raw materials are premixed by crane in line with different recipes which are precalculated on a computer. The premixing is a very important step because it is the basis for a correct sinter analysis. Adjustments are made at this stage to ensure that the mixtures of dusts and sludges are free flowing in the feed bins.

The premixed raw materials are discharged from the feed bins onto computer controlled feed belts and are transported by conveyor to a mixing and granulating drum. At this point lime and water are added in order to ensure the raw material mix has the optimum permeability. The raw material mix must be handled and transported with care until it is on the sinter machine to ensure that it remains permeable.

It is very important to produce a sinter with a constant chemical analysis and unvarying mechanical properties. In order to achieve this the sinter is analysed every three hours on the basis of an automatic sampling device. Statistical process control is an essential tool to ensure this objective is realised as it is critical that the process operates properly. Many measures have lead to an increase in productivity over the last years, figure 6.

Blast furnace process

DK has two small blast furnaces, figure 7, of which one is normally in operation, the second one is on stand-by.

DK's blast furnaces differ in some aspects from typical blast furnaces due to those elements in the

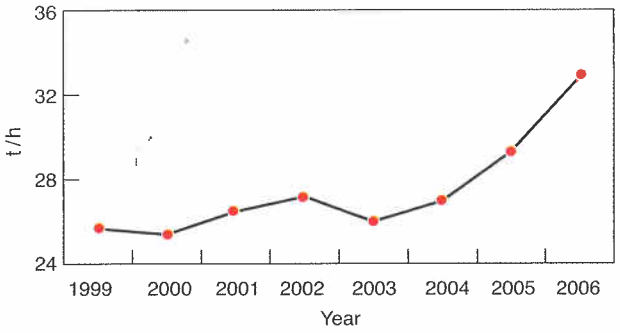
burden which cause severe operational problems. It is well known that zinc, alkalis and lead have an adverse effect on blast furnace operation and therefore special attention has to be paid to them [4]. They lead to a higher coke consumption, the formation of accretions and increased wear of the refractory material. Smooth and steady operation is needed for high production and this is interrupted by hanging and slipping. With a zinc burden more than 400 times higher (up to 45 kg/t HM) and an alkali burden up to 15 times (12 kg/t HM) higher than in normal blast furnaces one would expect problems. Yet the blast furnaces at DK can be operated without difficulty, providing close attention is paid to certain parameters. As can be seen from figures **8** and figure **9**, intensive process improvements have lead to a dramatic increase in productivity as well as an reduced reductant consumption.

Following years of intensive process observation special knowledge in the handling of zinc in the blast furnace process is now available at DK. Until recently it seemed that zinc was an element which only caused problems because it circulates from the top to the bottom of the furnace and back again. The zinc oxide in the burden is reduced by the CO contained in the reaction gas and then vaporises in the lower part of the furnace at temperatures of 900 °C. Carried in the rising stream of the reaction gas the zinc vapour condenses and oxidises in the upper parts of the furnace. Most of the zinc oxide will be carried down in the burden and once more be reduced. This circuit of reduction, vaporisation and condensation consists mainly of endothermic reactions and results in an increased coke consumption and therefore increased production costs. On the other hand the sludge from the gas cleaning plant appears as a pure zinc concentrate and can be sold to the zinc industry. Thus zinc has become an important revenue source. Figure **10** shows that from 1997 the quantity of processed zinc has increased from 5 000 to 8 000 t/a in 2005.

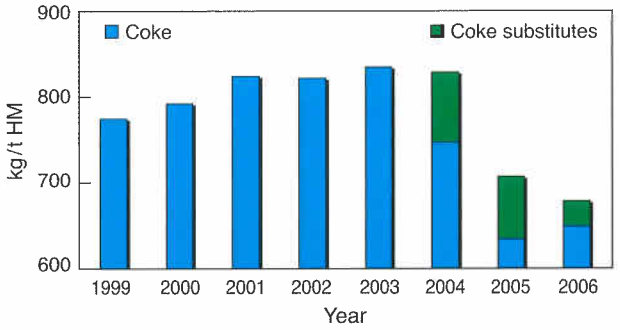
Environmental aspects

Sinter plants are still in the public eye as an important source of pollutants, mainly because of their huge amount of off gas. The recycling of steel mill wastes by sintering increases the concentration of PCDD/F, heavy metals and organic compounds in the sinter off-gas. In 1998 DK Recycling und Roheisen GmbH built an end-of-pipe filter system which reduces dioxins and furans as well as heavy metals, halides and SO_2.

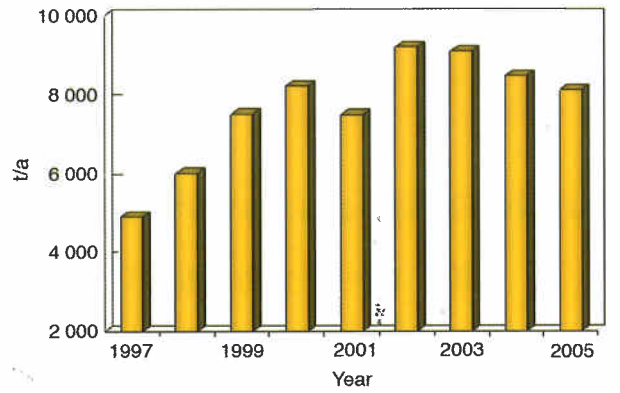
A material balance, figure **11**, shows the excellent recycling rate of DK's process. Only 2 % of 430 000 t of waste oxides processed, has to be dumped. This is the dust generated by the sinter off-gas cleaning systems.



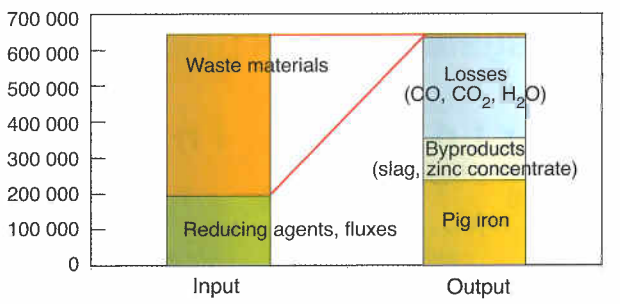
8
Development of production at blast furnace no. 3



9
Development of reductant rate for blast furnace no. 3



10
Development of annually processed zinc



11
Balance of the DK process

DK's service for the steel industry

Dumps are facing more and more pressure in Europe and are not a long term solution for steel mills waste oxides. As an external, independent and fair partner, DK offers a sustainable alternative to in-house recycling. DK recycles the waste oxides without any risks and investment for the steel industry by keeping all the necessary environmental duties. Long term contracts give a disposal guaranty and reliability for the steel works.

Outlook

DK is perfectly located in the centre of Europe. Within a radius of 1 100 km around Duisburg, eleven integrated steel works in EU 15 countries produce 64 million t crude steel [5]. If one assumes 30 kg/t of waste materials per t of crude steels, there is a raw material potential of 1.9 million t.

DK's aims for the coming years are the foundation of its role as a high quality pig iron producer for the German and European market by increasing the production to 330 000 t/a, as wells as expanding its role as the biggest recycling company for iron bearing waste materials by increase of the processed quantity to 570 000 t/a.

To achieve the goal, several projects are going to be realised in the near future, such as

- a new condensing turbine for the power plant
- an injection plant for solid reductants at the blast furnace
- substitution of two electrostatic precipitators in the sinter plant by two bag filter and
- a new raw material handling in combination with an intensive mixer.

Conclusions

DK has diversified from being simply an important recycling company for iron containing waste oxides, to being one of increasing importance for zinc containing waste materials as well. In this way, DK assists industry by recycling waste materials and thereby conserving raw materials, in addition it protects the environment by ensuring that materials are recycled rather than dumped. (S 31489)

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