THE DK PROCESS - A SOLUTION FOR THE BY-PRODUCTS OF THE EUROPEAN STEEL INDUSTRY

Karl-Josef Sassen and Carsten Hillmann

DK Recycling und Roheisen GmbH, 47053 Duisburg, Germany, hillmann@dk-duisburg.de

Abstract
During the production of iron and steel a notable amount of by-products are generated which could in principle be utilized in the iron and steelmaking process. Due to iron ores and scrap becoming worse in quality, the number and quantity of disturbing elements which hinder utilization, rises. The DK process, which consists mainly of a sinter strand and a blast furnace, has shown for now 30 years that there is a sustainable solution for such materials. The process preserves additionally about 340,000 tons of natural iron ore by using 425,000 tons of iron containing by-products from 7 steel companies in 6 different European countries.

Keywords: Recycling, zinc, dust, pig iron, sustainability

INTRODUCTION
In times of increasing raw material costs for the production of iron and steel, iron containing steel mill residues are in the focus as a source for “cheap” iron units. This might be right at first sight, but when it comes to a technique to recover the iron units and return them to the production process, it turns out that recovering these iron units is in the end more expensive than expected. Most of the proposed techniques have failed due to operational problems or non-profitable operation.

ACTUAL SITUATION ON RESIDUES
A lot of effort has been made so far to recycle as much iron residues from the steel industry as possible. The balance from the German steel industry in 2008 shows that most of the material is recycled which is indicated by the red bar (Fig. 1). But as far as the BOF dusts and sludges as well as the BF sludge is concerned, still a lot of material goes to internal or external dumps. Overall, the utilization rate is at 84 %.

It can be estimated, that a similar situation can be found in other European steel industries. Taking the specific production of dusts and sludges for the BF/BOF route of 48 kg/t crude steel [1], the production of 177.4 million tonnes of crude steel in the EU27 in 2011 [2] and the above mentioned utilization rate, one can estimate that an amount of at least 1.3 million tonnes of iron containing residues today is not used.

Fig.1: Situation of residues in Germany
COMPANY PROFILE

DK was founded 134 years ago as “Duisburger Kupferhütte”. Its aim at that time was to purchase big amounts of pyrite on the world market for its owners who made sulphuric acid out of it. After the roasting, DK recovered nearly every chemical element from the cinders – for example iron, copper, zinc, cadmium – even silver and gold.

- belongs to a trust
- 250 employees
- produces 280,000 tpy foundry pig iron
  => only producer in western Europe
- processes 460,000 tpy iron residues => biggest recycling company worldwide such material
- Turnover 2010: 92,000,000 €

Fig.2: Company profile of DK Recycling und Roheisen GmbH

With changing methods of producing sulphuric acid and an extremely complex and expensive production, the owner Rio Tinto Zinc decided in 1983 to close the plant. Due to the legal restraint to clear up the site, RTZ installed a trust and operations continued with the processing of the remaining cinders (Fig. 2). While doing so, more and more industrial wastes were added to the raw material mix and at the end of the day it came clear that the process can be operated only with industrial wastes.

In 1991 DK was renamed to DK Recycling und Roheisen GmbH to give expression to what the company does: recycling of wastes and production of pig iron.

The company still belongs to a trust, meaning that in the end the employees own the company. The actual number of employees is about 250.

RAW MATERIAL FOR THE DK PROCESS

Beside the fact that dusts and sludges from the BF and the BOF contain valuable iron units, there are other properties which limit their use in normal operations, like

- extreme low particle size which decreases productivity in the process, e.g. sinter plant,
- accompanying harmful elements, e.g. zinc and alkalis, which are absolutely detrimental to the process, especially the blast furnace
- varying analysis in every single residue

BOF dusts and sludges are the dominating raw material in the mix and account for approximately 60 % (Fig. 3). Sand is used for adjusting the basicity, small amounts of iron ore for adding some coarse particles to the mix in order to improve permeability.
Fig. 3: Raw material mix 2010

Besides BOF dusts with a high iron content and low harmful elements, there are BOF dusts with extremely high zinc contents as well as BF sludges with high carbon contents (Tab.1). Besides difficult chemical composition, also moisture contents between zero and 40 % makes operations difficult.

Tab. 1: Example of raw material compositions

<table>
<thead>
<tr>
<th></th>
<th>H₂O</th>
<th>Fe</th>
<th>Zn</th>
<th>C</th>
<th>S</th>
<th>CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOF dust 1</td>
<td>9,2</td>
<td>62,1</td>
<td>0,6</td>
<td>1,2</td>
<td>0,2</td>
<td>6,5</td>
</tr>
<tr>
<td>BOF dust 2</td>
<td>0,0</td>
<td>43,3</td>
<td>11,6</td>
<td>0,8</td>
<td>0,05</td>
<td>14,2</td>
</tr>
<tr>
<td>BF sludge</td>
<td>34,3</td>
<td>22,9</td>
<td>3,7</td>
<td>34,7</td>
<td>1,4</td>
<td>3,5</td>
</tr>
<tr>
<td>Mill scale</td>
<td>6,5</td>
<td>68,0</td>
<td>0,05</td>
<td>0,8</td>
<td>0,03</td>
<td>2,1</td>
</tr>
<tr>
<td>Iron ore</td>
<td>7,5</td>
<td>66,3</td>
<td>0,01</td>
<td>0,04</td>
<td>0,01</td>
<td>0,02</td>
</tr>
</tbody>
</table>

SINTER PLANT

Other than in a regular sinter plant, DK has no blending bed. The mixing of the raw materials is done by a grab crane. After mixing, the crane feeds several bins under which controlled feed belt weighers compose the material mix (Fig. 4).

There is another difference to a regular sinter plant: the cooling of the sinter is done in the last third of the belt – the “cooling strands” are only used as transport strands.
In 1999 DK build a second gas cleaning plant behind the existing electrostatic precipitator to keep the environmental limits for SO2 as well as dioxins and furans. The plant consists of an injection of lime of milk, injection of lignite coke and precipitation on a bag filter.

Although the raw materials have not improved but instead went into the opposite direction, the sinter productivity was raised considerably (Fig. 5).

**BLAST FURNACE**

The blast furnace plant consists of two rather small blast furnaces of which normally the bigger one, blast furnace #3, is operating. The pig iron, tapped every 2 hours from the blast furnace, is casted on a casting machine to form the product of DK, 8 to 10 kg heavy pigs (Fig. 6).

The gas cleaning of the furnace consists of two steps: a dry precipitation of coarse dust in the dust catcher and a wet one with the separation of fine and zinc carrying particles. The sludge of the wet gas cleaning is collected in the thickener and forms the second product of DK, the zinc concentrate.
Fig. 6: Blast furnace plant

Great improvements in blast furnace productivity have been achieved in the last 10 years (Fig. 7). Till mid of 2006 productivity was raised by process optimization and from mid of 2006 mainly due to the oxygen enrichment.

Fig. 7: Improvements in blast furnace productivity

Due to an extreme high zinc load of the furnace of 38 kg/t HM, the sludge from the waste water appears as a zinc concentrate with 65 to 68 % of zinc and very little impurities (Tab. 2). Compared to other secondary zinc raw materials the low contents of fluorine and chloride are an advantage.

Tab. 2: Analysis of DK Zinc concentrate

<table>
<thead>
<tr>
<th>Element</th>
<th>wt-%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>65-68</td>
</tr>
<tr>
<td>Pb</td>
<td>1.2</td>
</tr>
<tr>
<td>C</td>
<td>&lt; 2.0</td>
</tr>
<tr>
<td>Fe</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>F</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>Cl</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>Na</td>
<td>&lt; 0.10</td>
</tr>
<tr>
<td>K</td>
<td>&lt; 0.15</td>
</tr>
</tbody>
</table>

PIG IRON

Besides the capability of recycling a variety of steelmaking residues, DK is a producer of high quality foundry pig iron and is the market
leader in Europe for hematite pig iron. Tab. 3 shows only a few analyses out of the list of more than 80 different grades the company produces on a regular basis.

Tab. 3: Pig iron qualities

<table>
<thead>
<tr>
<th>Quality</th>
<th>% Si</th>
<th>% Mn</th>
<th>% P</th>
<th>% S</th>
<th>% C</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK M 0</td>
<td>1.0 - 1.5</td>
<td>0.7 - 1.0</td>
<td>0.0 - 0.12</td>
<td>0.0 - 0.05</td>
<td>3.5 - 4.0</td>
<td>Rest</td>
</tr>
<tr>
<td>DK M III</td>
<td>2.5 - 3.0</td>
<td>0.5 - 1.0</td>
<td>0.0 - 0.12</td>
<td>0.0 - 0.04</td>
<td>3.5 - 4.2</td>
<td>Rest</td>
</tr>
<tr>
<td>DK DKC</td>
<td>2.0 - 2.5</td>
<td>0.5 - 0.9</td>
<td>0.0 - 0.12</td>
<td>0.0 - 0.04</td>
<td>2.8 - 3.1</td>
<td>Rest</td>
</tr>
<tr>
<td>DK P-Eisen</td>
<td>2.0 - 2.5</td>
<td>0.5 - 0.8</td>
<td>1.2 - 1.7</td>
<td>0.0 - 0.04</td>
<td>3.5 - 3.8</td>
<td>Rest</td>
</tr>
<tr>
<td>DK Spiegeleisen</td>
<td>1.0 - 2.0</td>
<td>14.0 - 15.0</td>
<td>0.0 - 0.15</td>
<td>0.0 - 0.04</td>
<td>4.0 - 5.0</td>
<td>Rest</td>
</tr>
</tbody>
</table>

RECYCLING EFFICIENCY

The success of a recycling process can be measured by the amount of material which at the end of the process has to be treated as a waste material. The balance of DK in the year 2011 shows that only less than 1.5 % of the 500,000 tons of processed waste material had to be dumped (Fig. 8).

Fig. 8: Material balance of the DK process

CONCLUSIONS

Recycling of iron residues is not an easy job. In the last 30 years, DK has developed a process that not only recovers the iron units, but also the zinc units from steel mill residues. In this way, DK helps the steel industry to find a solution for residues that cannot be recycled internally and preserves valuable natural iron resources.

REFERENCES
