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THE HISARNA IRONMAKING PROCESS[1]

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Abstract
The HIsarna ironmaking process can use coal and fine ores directly and therefore doesn't require coking and ore agglomeration. The HIsarna concept is created by combining smelt cyclone technology of Tata Steel with the bath smelting technology of HIsmelt (Rio Tinto). The HIsarna development is part of the ULCOS project (Ultra Low CO_2 Steelmaking), a joint initiative of the European steel industry. The HIsarna process has the potential to reduce CO_2 emissions per ton with 20 to 80 %. Reduction with 80 % requires geological storage of CO_2. Because the HIsarna process operates with pure oxygen the off gases are practically nitrogen free. This makes the process well suited for CO_2 storage. The process can use more economically priced raw materials such as non coking coals and iron ores outside the quality range for blast furnace ironmaking. For instance iron ores with high levels of sulphur, phosphor, zinc, titanium or alkalines can be applied in the HIsarna process.
Therefore the process can offer economic benefits as well as environmental benefits.
Key words: Ironmaking; Smelting reduction.

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1. INTRODUCTION

The HIsarna ironmaking process cuts both carbon and costs. For today's steel industry the reduction of CO_2 emissions has become a key issue. Environmental factors are becoming more and more significant and the positive sustainability characteristics of the material in terms of recycling will not be sufficient to make up for the impact on the environment, moreover since the worldwide consumption of steel is expected to increase significantly due to population growth and increasing standard of living. Therefore ecological sustainability needs to be improved by rigorous improvements towards limitation of the CO_2 footprint of the process of iron- and steelmaking. Breakthrough technology is the only way to achieve this.

Another key issue for the steel industry is the cost of raw materials. The strong growth of blast furnace ironmaking capacity in Asia has resulted in high demand for raw materials in the specific quality range preferred for blast furnace ironmaking. A process that can operate with raw materials outside this quality range, such as the HIsarna process, can benefit from more favourable raw material prices.

The attractiveness of the HIsarna process lies in fact that it combines environmental as well as economical benefits.

1. 20 % primary energy and CO_2 saving (without geological storage) by the avoidance of cokemaking and ore agglomeration processes.
2. Easy ability to capture a high proportion (up to 80 %) of CO_2 for geological storage.
3. Ability to use thermal coals instead of metallurgical coals.
4. Ability to use low-quality iron ore feed materials.

2. ULCOS

In 2004, the ULCOS (Ultra Low CO_2 Steelmaking) research program was launched, an initiative of the major players in the European Steel Industry. The objective of ULCOS is to find innovative and breakthrough solutions for reducing specific CO_2 emissions, by at least 50% by 2050. For integrated production sites, the Blast Furnace Ironmaking route accounts for ~ 80 % of these CO_2 emissions. Therefore, ULCOS is focused on the development of new ironmaking technologies.

Up till 2006, many different technologies have been evaluated, after which the four most promising ones were selected for further evaluation and testing. These four technologies are:

1. Top Gas Recycle Blast Furnace (coal based)
2. HIsarna (coal based)
3. Ulcored (natural gas based)
4. Ulcowin (electricity based)

2.1. HIsarna

The HIsarna process was created by merging two processes; CCF pre-reduction technology and HIsmelt smelting reduction. The CCF technology was developed at Tata Steel IJmuiden (Hoogovens as it was then). In this concept pre-reduction amd melting of fine ores takes place in a smelt cyclone. The cyclone process has been extensively tested up to scales of 20 ton/hour of injected ore at Tata steel in IJmuiden and in Teesside Laboratories in the UK.

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HIsmelt originally started as an ironmaking modification of bottom-blown KOBM steel converter technology. A 2 ton/hour (hot metal) HIsmelt pilot plant was built and operated at Maxhütte, Germany in the 1980's, and this was followed by an 8 ton/hour (hot metal) pilot plant in Kwinana, Western Australia in the 1990's. As a next step HIsmelt built and operated a commercial plant that produced over 80 ton/hour in Kwinana. Although this plant has since been closed due to unfavourable market conditions and business outlook, the core process worked and considerable experience was gained with scale-up for this type of smelting reduction vessel.

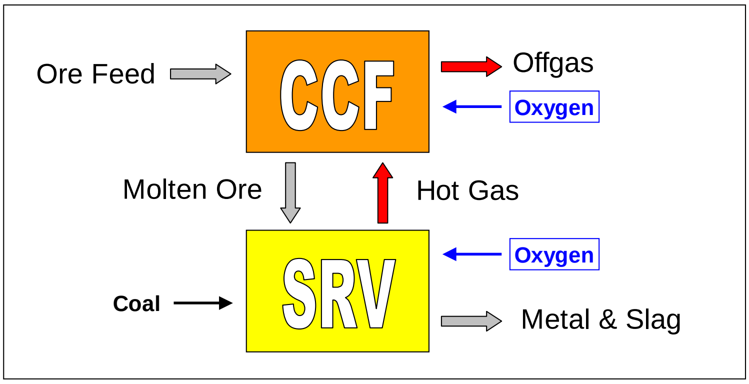

Figure 1. The two stages of the HIsarna process

ULCOS brought these technology streams together in 2006-2007. The basis was a "win-win" technology combination, leading to an ULCOS-supported pilot plant project in Europe in cooperation with Rio Tinto (HIsmelt) to prove the new process.

3. HISARNA TECHNOLOGY

The overall HIsarna concept involves two-stage countercurrent contact between iron ore and process gas. Both stages are operated above melting temperature, with molten partly reduced ore running downwards from the CCF into the SRV.

This two-stage process is highly integrated in a physical sense, and the two components are essentially operated as a single smelting furnace.

The process sequence can be described as follows:

(1) Iron ore and oxygen are injected into the CCF, where hot SRV offgas is burned and the resulting heat is used to melt and partially reduce the ore. The molten ore then runs downwards under gravity into the SRV below. The temperature of this material is expected to be around 1450 °C, and the degree of pre-reduction 10-20%.

(2) Molten ore dissolves directly into the slag, slag FeO is typically around 5-6%. Dissolved carbon in metal removes oxygen from the ore and a significant amount of CO gas is liberated. This reaction takes place in the reducing lower part of the vessel and is strongly endothermic. A heat source is needed to keep this part of the vessel in balance (see 4).

(3) Coal is injected into the bath to replace carbon which is used in the smelting step. The metal bath runs at 1400-1450 °C with dissolved carbon around 4.0%. There is essentially zero silicon present in the metal, and other minor impurities such as manganese are also present at very low levels (compared to blast furnace hot metal). Phosphorous and Titanium partition largely to the slag phase as oxides.

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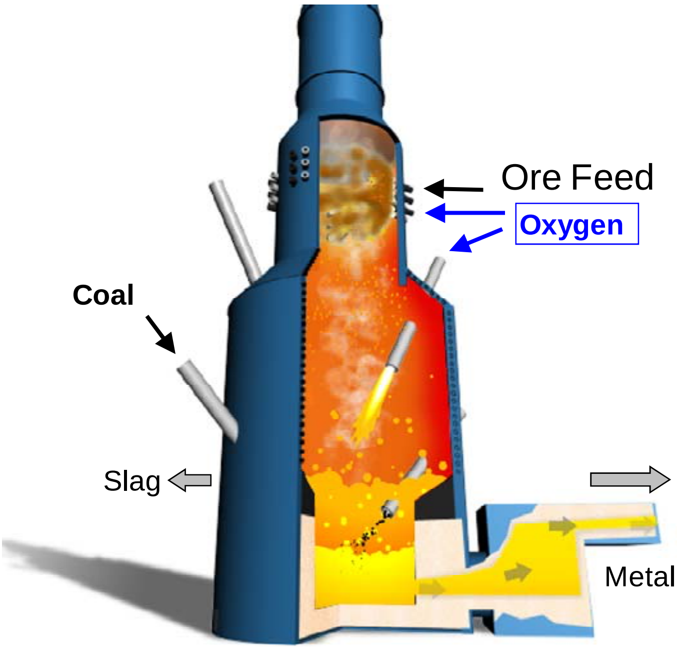

Figure 2. HIsarna furnace

(4) CO gas from smelting, together with gasification/combustion products from coal, provide an upward moving stream of hot fuel gas. This upward movement generates a large amount of splash, with metal and slag cycling through the upper section of the vessel as droplets. Oxygen is introduced into the upper section via lances, and heat is generated by post combustion. Heat is carried from the upper region to the lower region by these droplets.
(5) Partly combusted gas leaving the SRV then provides the necessary hot fuel gas for the CCF. This gas is typically around 1450-1500 °C and has a post-combustion degree around 50%.
The definition of post-combustion (PC) is as follows:

$$\%PC = 100(\%CO_2+\%H_2O)/(\%CO+\%CO_2+\%H_2+\%H_2O)$$

The aim is to achieve almost 100 % post combustion at the top of the cyclone. In which case the offgas will be highly concentrated nitrogen free CO_2. This will make the process well suited for a combination with CO_2 storage.

3.1. Raw materials

HIsarna doesn't require metallurgical coal types, and can use more widely available (lower cost) thermal coals. Considering that the supply of high quality coking coal is expected to become tighter in the future, it becomes clear that this is a major attraction of HIsarna.

In terms of ore type, HIsarna will have the same (well proven) ability as HIsmelt to reject phosphorous to slag. In HIsmelt around 90% of the phosphorous reports to slag – this is a direct result of its relatively oxidising condition (slag contains around 5% FeO). Although phosphorous tolerance may not be a major issue in some parts of the world, it does open possible exploitation of certain iron ores that would

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normally have been considered too high in phosphorous. A second possibility for non-conventional ore types is titaniferous magnetites. This type of ore is characterised by high titania levels and iron content around 55-60%.

Both ore and coal can contain high levels of alumina. This makes them less suitable for the blast furnace route, because of poor sinter properties and reduced blast furnace productivity. The HIsarna process has the capacity to operate with high alumina slag because the high FeO in the slag is a natural flux.

These features place HIsarna in a very strong position with regard to the potential to reduce the raw material costs of ironmaking substantially.

4. PILOT PLANT

The HIsarna pilot plant was constructed at the location of a former desulphurization plant at Tata Steel IJmuiden. This proved to be a very suitable location because of the good rail connection, the presence of the required utilities and an existing baghouse with suitable capacity. The construction was completed in April 2011. The design output is 8 t/h of hot metal (from around 13-14 t/h of ore feed). The coal injection capacity is 6 t/h.

Figure 3. HIsarna pilot plant at IJmuiden

With a production of 8 t/h of hot metal, there was an obvious call for appropriate logistics. Existing logistical routes are used as much as possible to facilitate the pilot plant. The iron source is ground pellet feed from the pellet plant, which is transported by a local contractor, about 15 t/h. The location of HIsarna is in an area with intensive rail traffic. The transport of slag and hot metal produced by HIsarna is done via rail. Existing slag ladles to collect the iron and the slag are used for this transport.

5. EXPERIMENTAL CAMPAIGNS

Operating the pilot plant is done in a 24x7 schedule. Each shift consisted of circa 10 people from various backgrounds, Operations and Research, from Tata Steel, the ULCOS partners and Rio Tinto.

The first campaign in May/June 2011 was the ultimate hot test of the combined CCF/SRV furnace. Although the individual elements of the process had worked before the combination was put to the test for the first time. Furthermore the furnace was operated with pure oxygen, a novelty for the SRV process.

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Figure 4. HIsarna casthouse

Figure 5. HIsarna control room

To quickly start-up the process a first fill of hot metal was transported in a 50-t ladle from the blast furnace to the HIsarna pilot plant. Once the metal was poured into the pilot plant, the maximum time slot was calculated based on the measured hot metal temperature and composition. Within this time slot the process had to be started in order to avoid the risk of a “frozen hearth”.

6. RESULTS

On the 20th of May 2011, after the second start-up, the first tap of hot metal was achieved. It was a major milestone for the technology and the team of HIsarna, which had been working towards this moment for many years. Further achievements of the first campaign are the hot commissioning of all the systems in actual operation, after solving all the “teething problems” of the new plant. In the first experimental campaign 60% of the injection capacity was achieved.

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Figure 6. First tap of the HIsarna pilot plant

7. FORWARD PLAN

Based on the evaluation of the first campaign, further improvements to the installation and the operating procedures have been made. In October/November 2012 the second experimental campaign is planned to take place. The objective of this campaign will be to achieve longer stable operating periods and achieve at least 80 % of the design capacity. A third campaign with the HIsarna pilot plant is scheduled for 2013.

8. CONCLUSIONS

The HIsarna project is a high risk/high reward innovation of the European steel industry united under ULCOS that can potentially have a strong **environmental** and **economical** impact.

The environmental benefits of the HIsarna process include the strongly reduced CO_2 emissions but are not limited to CO_2 only. Other emissions such as CO, fine dust, hydrocarbons, SOx and NOx can be reduced substantially because HIsarna doesn't require ore agglomeration or coking.

The economical benefits result from the use of low priced raw materials outside the normal quality range for blast furnace ironmaking.

The first campaign showed very positive results for a number of the key success parameters of the process and the equipment. More operating hours are needed to improve the knowledge of the process and the plant. This is the aim for the next campaigns.

The HIsarna pilot plant campaigns will continue under the "ULCOS-II umbrella" between 2012 and 2014

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