Press Release – Expert Article No. 2

Best practice in the steel industry: How the industry giants tackle the transformation towards climate-neutral production!

First green steel sets the direction

CO_2-free steel production can only be achieved by a technology shift from coking coal to green hydrogen and electricity from renewable energies. The first steel companies flag up promising ways to climate neutrality.

ArcelorMittal with Midrex – proven process for direct reduction

The direct reduction of iron ore in shaft furnaces has been a proven process used for decades with a potential for climate neutrality. One of the most productive technologies for producing direct reduced iron (sponge iron /DRI) is the Midrex process from Japanese company Kobe Steel, which accounts for roughly 60% of the global annual production of DRI and such derivatives as hot-briquetted iron (HBI). Midrex licensees include both the leading global metallurgy plant manufacturer SMS group with Paul Wurth, its subsidiary in charge of iron production, and its competitor Primetals.

Originally developed in the 60s by the US group Midland-Ross, Midrex direct reduction was taken over by German steel tycoon Willy Korf in 1974. 1976 saw the pioneer erect the first European electrical steel mill with a Midrex direct reduction plant in Hamburg, today one of the sites of the world's largest steel producer ArcelorMittal. During the Midrex process iron ore is reduced to solid sponge iron in a shaft furnace using a reducing gas mixture of carbon monoxide (CO) and hydrogen (H2) obtained from natural and process gas. This DRI is then molten with scrap and additives into steel in an electric arc furnace. In order to replace the fossil fuel natural gas by regeneratively obtained hydrogen for producing sponge iron, ArcelorMittal is building another Midex direct reduction plant at the Hamburg site. This demonstration facility is to initially produce direct reduced iron with grey hydrogen generated with natural gas; the conversion to green hydrogen from renewable energy sources will follow subject to sufficient availability and economic costs.

Salzgitter's concept for climate-neutral steel production with Energiron

Competing with Midrex is Energiron, a direct reduction technology developed jointly by the metallurgical plant manufacturers Tenova and Danieli. The first steel company to rely on the new process is Salzgitter AG. In a Letter of Intent dated March 2022 the company announces its intention to order – subject to corresponding grants pledged – a DRI plant with an annual capacity of 2.1 m tons for the future industrial production of DRI from Tenova.

The DRI plant with a nominal production capacity of 100 kg/h runs on hydrogen and natural gas evidencing the flexibility of the Energiron technology in terms of fluctuating availabilities of reducing agents including 100% hydrogen. By Salzgitter's account, this plant is the world's first direct reduction plant operated with hydrogen and natural gas in an integrated metallurgical plant. The DRI produced is used both in the blast furnace process for saving spray-blow coal and in the electric arc furnace of the Peine site.

Under the project name Salcos (Salzgitter Low CO_2 Steelmaking) Germany's third biggest steel producer after ArcelorMittal and Thyssenkrupp pursues a concept for shifting steel production from blast furnace to direct reduction in several steps.

As a first step from 2025, the CO_2 emissions are to be reduced by 30%. As a second step from 2030, a reduction by 50% is planned and by 2045 at least 95% of CO_2 emissions are to be avoided. Initially, direct reduction is to be achieved with natural gas, in the near future with green hydrogen based also on in-house wind power. For the complete conversion in 2045 steel will then be produced by direct reduction plants using green hydrogen and a green-power operated electric steel mill.

The overall concept includes the generation of green power from wind energy and the production of green hydrogen by electrolysis with wind power. To ensure green power supply the steel producer is erecting jointly with the regional energy supplier Avacon a wind farm with seven wind turbines and an OEM electrolyser by Siemens at the company premises. By company accounts, this is the first industrial sector coupling ever realised between regenerative power generation, hydrogen production and an industrial consumer.

In addition to the PEM electrolysis (Proton Exchange Membrane) Salzgitter is also looking at the production of hydrogen by means of the High-Temperature Electrolysis (HTE) from Dresden start-up Sunfire. Through its subsidiary Paul Wurth the SMS group as a leading global metallurgical plant manufacturer holds a share in this company.

In many industries such as the steel industry most waste heat – especially low-caloric heat with temperatures between 150°C and 250 °C – is not used but released into the atmosphere as steam. The novel high-temperature electrolyser by Sunfire uses this waste heat for producing hydrogen from green power with an efficiency never achieved before. Due to a substantial energy input from industrial waste heat in the form of steam the high-temperature electrolysis on the basis of solid-oxide electrolysis cells (SOEC) achieve an electric efficiency of over 82%. Conventional electrolysis processes hardly achieve 60% since they have to operate with liquid water which is more energy-intensive.

By the end of 2022 the HTE electrolyser is expected to have run for 13,000 hours and produced a minimum of 100 tons of green hydrogen. The hydrogen produced in this way is initially used for steel annealing and therefore constitutes an important milestone on the roadmap to hydrogen-based steel production.

Salzgitter has already started its green steel production and concluded an agreement with the BMW Group on the supply of low-CO_2 produced steel. From 2026 this steel is to be used for the mass production of automobiles in the European factories of the BMW Group.

Thyssenkrupp – new ways at an old site

The shift from coking coal to hydrogen for steel production is a mammoth task. The magnitude of this challenge becomes obvious when looking at Thyssenkrupp as an example. This, the biggest European steel site in Duisburg, emits 2.5% of the German CO_2 emissions, i.e. ten times as much as domestic air travel annually. Related to its home region of the Ruhr Valley, one in four tons of this climate gas is emitted by Thyssenkrupp Steel.

Thyssenkrupp also views renewable energies and green hydrogen instead of coal as the solution. According to Bernhard Osburg, Chairman of the Board at Thyssenkrupp Steel Europe AG, the technical challenge lies in integrating the direct reduced iron into the downstream processes of the plant. Unlike other steel producers Thyssenkrupp does not intend to melt solid sponge iron from the DRI plant in an electric steel mill to be newly erected but in the existing oxy-steel facility. For this Thyssenkrupp Steel has broken new ground. The approximately 500°C hot and solid sponge iron is not meant to cool off first but be liquefied in a downstream melter leveraging the heat. The resulting molten pig iron can then – like the blast-furnace pigs previously – be converted into steel in the steel mill's converter subject to adding scrap and additives. What changes is the pig iron production, while the downstream part of the plant stays the same. The blast furnace just needs to be replaced by a direct reduction plant with melter while the remaining steel site remains unchanged in terms of equipment. The major added benefit here is that the steel-making formulas do not have to be changed. When shifting to an electric arc furnace the formulas for the 2,500 steel grades would have to be adapted – like when switching from a wood-fired stove to an induction cooker in your kitchen. By 2030 Thyssenkrupp wants to cut CO_2 emissions by 30%, some 6 million tons. This would be the same effect as if 3 million cars with combustion engines were replaced by e-vehicles.

Hüttenwerk Duisburg is a process-integrated, energy self-sufficient metallurgical plant. The cupola gas from the blast furnace is used for in-house power generation and covers some two thirds of in-house demand. The process heat generated at the site additionally provides distant heating for 20,000 households in the Duisburg region. The direct reduction with hydrogen generates steam rather than cupola gas, which cannot be converted into electricity. In future, after the shift to direct reduction, power will have to be bought in – amounting to approx. 50 terawatt hours per year, which corresponds to the electricity demand of 40% of all German households. Then high volumes of green hydrogen will also be required, in Duisburg this amount would correspond to the contents of filling the gasometer in Oberhausen twice per hour – which measuring 115.5 m in height and 67.6 m in diameter used to be the biggest gasometer in Europe.

SSAB – first CO_2-neutral steel in the world

The decarbonisation of steel production is also an issue addressed outside of Germany. In August 2021 the Swedish company SSAB reported producing the world's first CO_2-neutral steel in a pilot plant as part of its Hybrit Project and having delivered a first test batch of sheets to automotive manufacturer Volvo. Hybrit was the first Swedish joint venture established by SSAB with iron ore pellet producer LKAB and energy supplier Vattenfall. By 2026 SSAB wants to supply the market with climate-neutral steel on a commercial scale. By then the blast-furnace route in Oxelösund is expected to be converted to direct reduction with green hydrogen based on the Hybrit Process for sponge iron production and an electric arc furnace for melting the DRI for steel production.
The Swedes have already found a volume buyer in Mercedes-Benz. As early as possible the CO_2-neutral steel is to be introduced in vehicle production. The first prototype parts for bodies in "fossil-free" steel – this is the internal name used by SSAB – are already planned for this year. In 2039 if not before Mercedes-Benz' new passenger car fleet is to become CO_2-neutral along the complete value chain.

The Hybrit Project and its founders have inspired the start-up H2 Green Steel to initiate a greenfield project for CO_2-free steel production in the Boden-Luleå region in North Sweden. The planned electric steel mill includes not only a direct reduction plant but also green hydrogen production that will be integrated into the mini steel mill. Construction work at the site is planned to start in 2024. From 2030 the steel mill is to produce five million tons of steel annually, including sheet steel for the automotive industry.

Voestalpine bets on hybrid technology with Primetals and Siemens

In Austria Voestalpine has determined the shift from coal-based blast-furnace technology to green-power based electric arc furnace technology by launching the greentec steel project. Using a hybrid technology with electric arc furnaces the CO_2 emissions are to be reduced by some 30% in a first step by 2030. This corresponds to a saving of some 3 to 4 million tons of CO_2 per year, an amount that accounts for almost 5% of Austria's annual CO_2 emissions. In order to achieve the target of a CO_2-neutral production by 2050, the steel group wants to gradually increase the use of green power and hydrogen as well as of the by then climate-neutral pre-product sponge iron (DRI or HBI) in the steel production process. In summer 2022 infrastructural remodelling is to start at the two sites in Linz and Donawitz, in early 2027 one arc furnace each could then be commissioned in Linz and Donawitz. With a view to generating green hydrogen the company has already installed the world's biggest PEM hydrogen pilot plant by Siemens at the Linz site. Green power from hydropower is provided by the "Energieversorger Verbund".

Beyond this, Voestalpine has a patent on the production of sponge iron (DRI or HBI) in a direct reduction process with green hydrogen and biogas. The biogenic carbon here makes for the carburisation of sponge iron for efficient melting in the electric arc furnace.

As early as April 2021 a plant developed by Primetals was commissioned at the Donawitz site for hydrogen-based fine ore reduction. This pilot plant operates with the world's first direct reduction process for iron ore concentrates from ore beneficiation that does not require any agglomeration like sintering or pelletizing. Called Hyfor (Hydrogen-Based Fine-Ore Reduction) this process is the only one in the world to process iron ore concentrates with 100% particle sizes below 0.15 mm while being suited for a wide variety of ores like hematite and magnetite.

Donawitz is also the site of a research plant for the CO_2-free production of crude steel in one process step using novel hydrogen plasma technology. Here, steel is to be produced without the pig iron stage by reducing ores with hydrogen plasma in a type of electric arc furnace in future. To this end, the principle of the electric arc is used, which also underlies lightning discharges in the atmosphere. Under high voltage the gas is ionised, hence becoming plasma and conductive. In this process the hydrogen is used, on the one hand, to reduce the iron oxides, and its energy in the plasma phase, on the other, to melt the metallic iron. The ore is molten and reduced at the same time and here steam rather than CO_2 is generated. Next to Voestalpine the mining university Leoben is also involved in the basic research project of the “Metallurgisches Kompetenzzentrum K1-MET”.

Saarstahl – hydrogen site with Paul Wurth in France

In the French city of Dünkirchen the steel companies Liberty Steel and SHS – Stahl-Holding-Saar intend to erect a hydrogen-based steel complex in cooperation with plant manufacturer Paul Wurth (SMS group). The Letter of Intent focuses on developing a 1GW hydrogen plant based on Sunfire THE technology and a 2-million-ton DRI plant near the site of aluminium producer Alvance – by Liberty Steela accounts, a company of the GFG holding of the British-Indian steel tycoon Sanjeev Gupta. The advantage of the site on the French coast is that low-cost nuclear power is permanently available in addition to wind power.

The DRI plant is to initially use DRI and hot-briquetted iron (HBI) with a mixture of hydrogen and natural gas as a reducing agent and switch to 100% hydrogen after electrolysis technology is completed. The produced DRI/HBI is to be predominantly used in the electric arc furnace by Liberty Ascoval in France. Surplus output will be used in Liberty’s integrated steel mills in the Czech Republic (Ostrava) and Romania (Galati) as well as in the SHS, Dillinger and Saarstahl works in Germany.

Electrification of steel production – the future

Experts like Dierk Raabe from the Max-Planck Institute for Iron Research are convinced that electrometallurgy holds further potential. In future, the direct electrolysis of iron ore with green power could substitute pig iron production with hydrogen – similar to the production of primary aluminium. Since time immemorial, aluminium has been made with electric energy, which today is already in part obtained from regenerative sources such as hydropower. In the melt flow and/or aluminium electrolysis the light metal is produced from aluminium oxide, which was previously obtained from the aluminium oxide bauxite.

Other metals and even iron can be produced by means of electrolysis. This energy-intensive process requires lots of power, which has so far not made economic sense because of the high electricity prices. As long as power generation largely depends on coal-fired power plants the energy-intensive electrolysis emits far more carbon dioxide than conventional iron production via the blast-furnace route, according to the study by the steel institute VDEh.

Boston Metal – CO_2-free steel production with electrolysis without hydrogen

At the US company Boston Metal people are convinced that the electrometallurgical electrolysis of iron ore will reach market maturity soon. The MIT spin-off wants to optimise the process for CO_2-free steel production with its Molten Oxide Electrolysis (MOE) process. Dropping the interim step of green hydrogen production for reducing iron ore, the MOE process uses direct current for separating oxygen from the iron ore in a single-step process at approximately 1600° Celsius.

In Molten Oxide Electrolysis an MOE cell is filled with iron ore and a liquid electrolyte. An inert metallic anode is dipped into this iron-ore containing mixture and the iron ore is molten introducing direct current. According to Boston Metal, the result is a clean, high-purity crude steel that can be directly fed to ladle metallurgy.

Boston Metal's further plans are quite ambitious. As early as 2023 they want to start producing ferroalloys on pilot plants, a demonstrator for steel production is announced by 2025 at the latest. In the second half of the century commercial steel production is expected to get started.

The investors that Boston Metal already succeeded in winning over for their vision of an efficient CO_2-free electric steel production also include a

German flagship company: BMW. In 2030 the automotive manufacturer wants to see some two million tons of CO_2 emitted less by its steel supplier network, as BMW Chief Purchasing Officer Andreas Wendt specified. However, he did not specify which suppliers.

Innovative processes from the metal-working industries and the steel sector will be on show at the leading global trade fairs GIFA, METEC, THERMPROCESS and NEWCAST in Düsseldorf from 12 to 16 June 2023. The ecoMetals campaign of Messe Düsseldorf will make reference to the ecological path of these industries and promote companies that invest in innovative, environment-saving and sustainable technologies.

For more information plus industry and company news on the trade fairs visit www.tbwom.com

Author: Gerd Krause, Mediakonzept (Düsseldorf)

Press Contact:
Messe Düsseldorf GmbH
Larissa Browa
Tel.: +49 (0)211-4560 549
E-Mail: BrowaL@messe-duesseldorf.de

Düsseldorf, April 2022

++

LinkedIn: http://www.linkedin.com/groups/7442674
Facebook: http://www.facebook.com/TheBrightWorldofMetals
Twitter: www.twitter.com/tbwom

GIFA METEC THERM PROCESS NEWCAST

The Bright World of Metals

12–16 June 2023
Düsseldorf/Germany

15th International
Foundry Trade Fair
with Technical Forum

11th International
Metallurgical Trade Fair
with Congresses

13th International Trade Fair
and Symposium for Thermo
Process Technology

6th International
Trade Fair for Castings
with NEWCAST Forum

www.tbwom.com

Messe
Düsseldorf