CO₂ emission reduction: A need for the future

Given the need to limit global warming to 1.5°C compared to pre-industrial levels and the major contributing impact of the steel industry, Paul Wurth has been developing a range of CO₂-reducing BF technologies that aim to reduce emissions in a stepwise mode as political and cost uncertainties become clearer or even more urgent.

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The Paris Agreement negotiated at the 2015 United Nations Climate Change Conference (COP 21) set the goal of limiting global warming to well below 2°C, and, preferably, 1.5°C compared to pre-industrial levels. According to scientists, this 1.5°C goal will require zero emissions some time between 2045 and 2060, and they are therefore calling for immediate action.

The iron and steel industry is one of the major sources of industrial CO₂ emissions. Within an integrated steel plant, 70-80% of the carbon input is attributable to the ironmaking process, but only 20-25% of the CO₂ emissions are directly generated by the blast furnace (BF). Coke-based BF technology, known for more than 300 years, is still considered the most economic route for producing hot metal, at least in Europe. BFs are more flexible and dynamic with respect to ore quality and they excel in terms of production capacity compared to other ironmaking routes. Owing to these advantages, the BF-converter route represents the major share (60-70%) of the total crude steel production in the world today.

To comply with the targets set by the Paris Agreement, steel plant owners and operators have to implement drastic measures to cope with future CO₂ emission reduction requirements. Political uncertainty makes it very difficult for them to define measures for technological shift, as moving away from the traditional BF route implies very high costs and puts at danger the profitability of the complete steel plant, with a real risk of losing competitiveness in the global market.

Having always been committed to providing pragmatic solutions to its customers, Paul Wurth is presently developing in an intensive way a number of technologies applicable to the classical BF route for allowing a stepwise reduction of CO₂ emissions, and which are well balanced between ambitious environmental targets and given economic constraints. These solutions mainly concern the efficient utilisation of off-gases produced by a steel plant for reaching progressively lower emissions.

METALLURGICAL USE OF PROCESS OFF-GASES

While BF operation is responsible for 70-80% of the carbon input for the steel plant, the direct CO₂ emission related to the BF is only 20-25%. The remaining carbon exits it in the form of BF gas, which is used as fuel in a variety of steel plant units, such as the coke oven plant, the sinter plant and rolling mills. Similarly, a large amount of carbon is exported from the coke oven plant in the form of coke oven gas to the different units of the steel plant. The volume of process off-gases such as coke oven gas, BF gas and basic oxygen furnace gas generated within a steel plant is much higher than their internal use as a fuel. The surplus is used mostly in power plants for the production of electricity.

By applying technologies that allow the use of all process off-gases for metallurgical purposes within the blast furnace, CO₂ emissions from steel plants could be significantly reduced. In this case, the required electric energy, preferably from renewable sources, can be bought from an external power grid.

UTILISATION OF COKE OVEN GAS IN BFS

With a high calorific value (16-18MJ/Nm³), coke oven gas (COG) is a potential energy source allowing substitution of coke in the BF, and thereby leading to CO₂ savings. COG can be injected into the BF either at tuyere level or at lower shaft level. Use of COG at the BF tuyeres increases the lower heating value (LHV) of the BF top gas. Presently in integrated steel plants, COG is used mainly in the hot blast stoves, reheating furnaces and coke oven plants, whereas process off-gases with lower calorific value are consumed in power plants. In order to use COG for metallurgical purposes in the BF, internal redistribution of gases within the steel plant is required and so internal electric power production will be reduced.

COG TUYERE INJECTION

COG injection at tuyere level is relatively easy to implement and has been known for decades. Paul Wurth is proposing different technologies, and has designed a new tuyere
injection system via a separate lance for a COG utilisation rate of 15,000-30,000Nm³/h.

COG can be injected in the BF as a substitute for natural gas, pulverised coal or coke. For economic reasons, however, customers often prefer to maintain a high rate of pulverised coal injection (>150kg/THM), benefitting from the difference in market price of PCI coal and expensive coke. Considering that injection of cold COG along with a high rate of pulverised coal leads to a significant drop in the raceway adiabatic flame temperature (RAFT), only a relatively small amount of cold COG can be injected into the tuyeres. This limits the CO₂ saving potential of this technology to approximately 3-4%. A schematic diagram is shown in Figure 1.

**COG SHAFT INJECTION**

COG injection in the lower shaft of the BF is an alternative technology to utilise a higher amount of COG in the BF (see Figure 2). Shaft injection is advantageous in many ways as it does not limit furnace operation in terms of RAFT. On the contrary, it improves the top gas temperature thanks to a larger shaft gas volume.

In the case of shaft injection, COG temperature should be equivalent to the temperature of the lower shaft (900-1,000°C) in order not to cool or overheat the shaft zone. However, heating up COG to such high temperatures brings about many technological challenges, such as carbon deposition and poisoning of the reactor surface due to impurities present in the COG. Furthermore, this option may lead to a redistribution of temperature isotherms near the shaft wall. To overcome these problems, reforming of COG can be carried out to convert the contained hydrocarbons into H₂ and CO. Paul Wurth is presently working on the development of a COG reforming technology based on partial COG oxidation.

Combining tuyere and shaft injection allows significant savings in CO₂ emissions (up to 10%), as the entire COG present in the steel plant is used. For higher CO₂ savings from steel plants it is essential to develop technologies that use not only coke oven gas but also convert blast BFG into fuel suitable for use in the BF.

**UTILISATION OF BFG AND COG**

Proposals to use BF gas within the BF have already been made in the past – for example, in the ULCOS (Ultra Low CO₂ Steelmaking) project. The idea is to capture the CO₂ contained within the BF gas and re-inject the remaining portion of the gas into the tuyeres of the BF and/or shaft.

A major concern is the current lack of any profitable use of the huge amount of CO₂ captured from a typical industrial BF. Therefore, Paul Wurth is following another concept based on dry reforming, in which hydrocarbons react with CO₂ to produce H₂ and CO-containing reducing gas. Paul Wurth is developing a technology to execute the dry reforming reaction at a higher temperature level not requiring a catalyst, which is usually prone to poisoning with COG.

Laboratory tests have been conducted to define the best process conditions for this approach. The process takes place in a specially designed regenerative heat exchanger (a modified hot blast stove), which will convert the COG/BFG mixture into hot syngas.
The COG dry reforming hot stove operates in a similar way as a conventional hot blast stove. The compressed COG and BF gas will be reformed and heated to a temperature similar to the hot blast temperature (1,100-1,300°C). The generated hot syngas is then injected as reducing gas into the BF at tuyere level or at shaft level by mixing with suitable cold reducing gases. A schematic flow diagram is shown in Figure 3.

This technology provides the opportunity to exploit a significant amount of process off-gases in the BF, thereby achieving CO₂ savings. Compared to the ULCOS BF, this process is interesting since it is based on hot blast stove technology, well known to steel plant operators and not requiring complex equipment.

**STEPWISE MODIFICATION OF BF PLANTS**

Considering political indecision regarding a CO₂ emissions trade and cap system and the tremendous investment needed to switch to new technologies and any related competitiveness risk for European steelmakers against the global market, the actual CO₂ reduction calendar is uncertain.

A solution could be a stepwise CO₂ reduction approach based on the modification of existing installations, together with retrofit integration of renewable power in the processes. COG dry reforming technology fits into this scheme and would allow stretching the required investment in four steps over the time.

- The first step of the COG dry reforming concept targets 17-18% of CO₂ savings. It involves the shift of the steel plant’s off-gases from usage in the power plant to injection in the BF, facilitated through internal redistribution of off-gases to avail the entire COG for dry reforming.
- The second step targets up to 30% reduction of CO₂ emissions and is based on the use of the entire COG and BF gas for dry reforming and the injection of natural gas at different steel plant units.
- The third step targets up to 40% of CO₂ savings and includes the electrification of the steel mills, i.e., replacement of all possible burners in reheating furnaces, coke ovens, sinter plants and other production units by electrical systems (for which the electricity would be produced from non-fossil renewable energy sources).
- The fourth step involves the complete substitution of hot blast by oxygen injection in the BF and provides easy CO₂ capture possibility from the BF.

**CONCLUDING REMARKS**

As the off-gas distribution and usage varies from one steel plant operator to another, Paul Wurth assists customers in the development of plant specific CO₂ reduction strategies and has available now a number of CO₂-saving technologies. Driven by its pioneering spirit that has marked traditional ironmaking throughout decades, Paul Wurth is committed to leading the transformation towards finally carbon-free iron ore reduction.

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