Efficient ironmaking at low cost and with reduced environmental impact

Currently, with limited raw materials availability, reduced margins and tightened environmental constraints, Paul Wurth has focused its efforts on increasing the efficiency and pollution control in cokemaking, sinter production and ironmaking. Examples are described.

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COKE MAKING

The single oven pressure control (SOPRECO®) technology allows control of the appropriate pressure conditions in every individual oven of the battery during the entire coking process. Maintaining negative pressure in the collecting main results in an optimised suction effect and ensures significant reduction of gas emissions from doors and lids during the initial phase of distillation. Further, it is possible to stabilise each single oven at constant pressure during its total distillation time, independent of pressure fluctuation in the collecting main. Higher positive pressure operation in the final stage of distillation becomes possible, resulting in improved coking results. Coke battery operations with the oven individualising SOPRECO control systems can reach a 90% reduction in secondary emissions at coke oven doors, lids and stand pipes.

The control of SOPRECO valves can also be directly integrated into Paul Wurth's SUPRACOK™ level-2 automation solution for coke oven plants. This package features modules and models for thermal control, coal coking process, cycle scheduling and oven health. It is a powerful tool for improving operation stability and coke quality, increasing battery lifetime and reducing fuel consumption as well as emissions. An example installed at the B3 coke oven battery of Zentralkokerei Saar (ZKS), Dillingen, Germany, is shown in *Figure 1*.

Fig 1 **SOPRECO® valves**

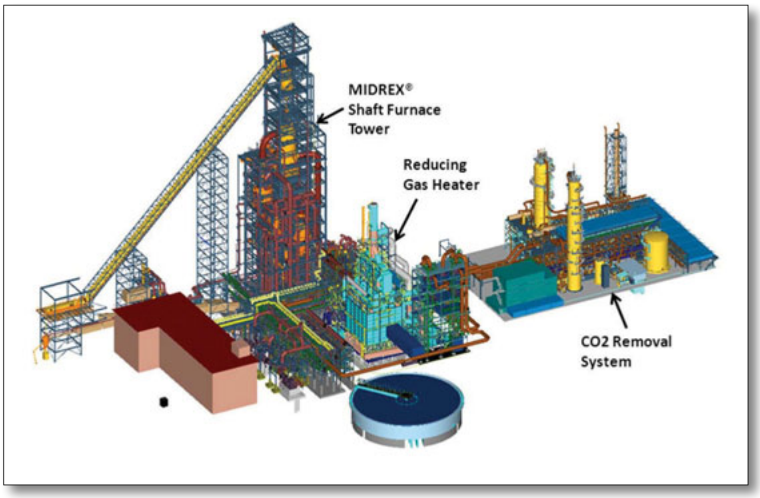

Fig 2 **Typical MIDREX® MXCOL® plant configuration**

Possible use of excess gas The typical output of coke oven gas is about 450-500Nm³ per tonne of produced coke. Especially for standalone coke oven batteries, the question of further use of the gas can offer up several answers. Coke oven gas has about 25-35% methane, 5-10% CO and 55% H_2, with the potential for being burnt for the production of electricity or serving as reducing gas for iron production. Assuming the coke oven gas has a calorific value of 17.6MJ/Nm³ and a power plant generation efficiency of 45%, the yield of electric power would be 0.96MWh from one tonne of coke. Alternatively, a coke oven gas-based, MIDREX® MXCOL® Plant (see *Figure 2*) engineered by MIDREX licensee Paul Wurth would produce 0.7 tonnes ▷

Fig 3 **Circular sinter cooler at ArcelorMittal Tubarao, Serra, ES, Brazil**

Fig 4 **BF 'I', 2.5Mt/yr ironmaking plant of TATA Steel Ltd, Jamshedpur, India**

of DRI per tonne of coke. Thus, it is more profitable to produce DRI than electricity provided that the selling price of 1 tonne of DRI is at least 10% higher than the price of 1MWh of electric power. Additionally, DRI production via MIDREX technology is superior to power generation, from an environmental point of view, particularly thanks to the lower specific NO_x and SO_x emissions **[1]**.

SINTERING

With respect to the increasingly difficult raw materials supply (cost, quality, fines content, addition of secondary feed materials, such as dust and sludge), facing the industry today, Paul Wurth has combined its experience in bulk materials handling, segregation and flow control, off-gas treatment, plant building and process automation, into an own solution for sintering. The concept represents an integrated approach to the overall operation of a modern sinter plant as well as to its individual process steps. Raw mix preparation, the sintering process, sinter cooling, processing and handling of the output material, off-gas treatment and heat recovery, are equally covered. The aim is an overall balanced solution for the best performance of a given sinter plant whereby the plant units and the technological process are supported by modern instrumentation, control and automation. The level-2 SINTERXpert™ system integrates mix calculation, online mass balance, process control and the use of mathematical models, thus providing the operator with an optimisation tool for process flexibility in the frame of the required production and efficiency.

Driven by the declining quality and increasing price of available raw materials, high intensive mixers are used in material preparation which helps reduce the cost of sinter production. In addition, this technology allows for an increase in the use of residues in the sinter mix, thus improving the steel plant's overall iron yield and contributing to sustainable operations.

The complexity of the sintering off-gas may call for either selective or combined gas treatment technologies, depending on the legislation for emissions of dust, fine dust, sulphuric compounds, NO_x, CO, dioxins and furans. Paul Wurth has the knowledge and experience to design off-gas systems as tailor-made solutions to fit each operator's specific needs, including dry, semi-dry and wet systems. In particular, Paul Wurth had earlier developed the EFA™ technology, which represents a combined off-gas treatment, a proven solution for removal of fine dust, sulphuric and chloric compounds, dioxins and furans. This is a future-orientated technology that allows the use of lower quality raw materials. Calculations for plants operating with EFA have shown that the respective savings in purchasing can reduce the sinter production cost by €1/t **[2]**.

Different technologies of sinter cooling can be applied, taking into account capacity requirements and layout restrictions. By employing new mechanical concepts and fluid dynamics simulations, existing cooler types, such as the circular cooler were re-designed (see *Figure 3*), so optimising the cooling efficiency and solving many of the known problems of conventional coolers. In reline conditions with restricted space, these solutions can be applied to increase the cooling capacity without plant extension.

Heat recovery and partial waste gas recirculation are solutions for improving energy efficiency, being applied on a tailor-made basis to fit each individual customer's needs.

BLAST FURNACE IRONMAKING

Bell Less Top Since its first installation in 1972, Bell Less Top® (BLT®) technology has become the industry standard for charging burden into the blast furnace. The installation of a BLT usually results in an increased production rate of about 5% and, at the same time, lower fuel rate and CO_2 emissions of the same order of magnitude. Continuous innovation made the BLT applicable to any size of blast furnace and to any specific requirements on raw materials properties and segregation, and on operation and maintenance strategies. Today, there are more than 700 installations, such as that in *Figure 4*, producing over 60% of all hot metal worldwide.

A recent innovation is the pressurised cooling concept for BLT's main gearbox. This closed-loop water cooling system isolates cooling water completely from the blast furnace atmosphere and so avoids contamination. Pressurised cooling is maintenance-free, provides maximum cooling capacity resulting in longer equipment lifetime, and reduces operation cost by lowered water and nitrogen consumption.

Coal injection Industrial application of pulverised coal (PCI) into blast furnace hearths began in the early 1980s. Pulverised coal is now considered the most flexible, potent and efficient coke-replacing reducing agent in blast furnace ironmaking. In recent years, injection rates of more than 230kg/tHM have been reported from several well-performing blast furnaces globally. Since the coal for injection requires minimum preparation, PCI is a nearly emission-free replacement for metallurgical coke. Taking into account the high replacement potential and subsequent reduced requirements in coking coal/coke tonnages, significantly reduced CAPEX and OPEX can be demonstrated for the whole production chain upstream of steelmaking.

Energy efficiency Waste gas heat recovery at the hot stoves of a blast furnace leads to energy savings of about 10% of the necessary input for hot blast generation. On the blast furnace gas side, a top gas energy recovery turbine (TRT) can produce electricity sufficient for about 30% of the energy required for cold blast generation.

Process automation For most operators, recent years have seen larger variations in the raw materials supply, which calls for increased flexibility. Paul Wurth's automation solutions include the level-2 BFXpert® system integrating modern measuring techniques, equipment, process know-how and mathematical modelling into an efficiency and economy tool for smooth, reproducible, predictable operation.

BLAST FURNACE SLAG

Since its invention in the 1980s, direct, water basin granulation of the blast furnace slag with dynamic dewatering via the INBA® drum officially became a Best Available Technology (BAT) **[3]**. The quality of the slag sand, particularly its high glass content, is the basis for the commercial success of this technology – these properties made the metallurgical byproduct a valuable raw material in the production of cement. About 75% of the blast furnace slag produced is used by cement producers in developed countries that have steel and cement industries. In Germany, for instance, only 4% of the BF slag goes to intermediate storage without direct use **[4]**.

Today's state-of-the-art slag granulation is a fully automated plant for the production of slag sand with maximum pollution control; usually it is run as a cold water system with steam condensation. This ensures the lowest sulphuric emissions to the atmosphere (H_2S at 10-25mg/Nm^3; SO_2 at 20-85mg/Nm^3) and the lowest specific water consumption of all known water-based granulation techniques at 0.7m^3/t of slag **[5, 6].**

RECYCLING OF IRON-BEARING RESIDUES

Increasingly severe environmental legislation, a shortage of certain raw materials and cost constraints are the reasons why metal-bearing residues are increasingly considered as valuable by-products.

RedIron™ is a direct reduction process using a Rotary Hearth Furnace (RHF) for converting steelmaking residues into DRI (Direct Reduced Iron) or HBI (Hot Briquetted Iron). Blast furnace dust and sludge, BOF dust and sludge, pellet fines and mill scales can be combined, thus making up a mix of return materials which covers all residues of an integrated steel plant. The product is a material which can be directly recycled into the main technology chain by becoming an additive charge into blast furnaces, converters or EAFs.

In 2010, Lucchini's steel works at Piombino, Italy, commissioned a RedIron™ plant, designed and constructed by Paul Wurth (see *Figure 5*), which recycled 60,000t/yr of ferrous residues and produced 40,000t/yr of HBI returned to the iron and steelmaking facilities. Thus, the cost of shipping and dumping residue material was avoided.

RedSmelt™ is a two-step process of pre-reduction and smelting, based on a combination of a RHF and an EAF. It may be used for the conversion of steelmaking residues and/or iron ore into pig iron (or similar alloys) and slag. The technology is especially good for processing a wide quality range of one kind of fine material, for instance ore. Feasibility has been demonstrated for hot metal outputs of 0.3-1.0Mt/yr. The economic effect depends on specific local conditions, mainly on input material quality, availability and cost of reducing agents and electricity.

Primus® is a two-step process of pre-reduction and smelting, based on a combination of a Multiple Hearth Furnace (MHF) and an EAF. It is designed for processing residues with particularly high zinc content, for instance, regular EAF steelmaking dust. The products are pig iron of BF hot metal quality, saleable inert slag and a zinc oxide product (more than 55% Zn) which can serve as a secondary input material for the zinc industry. Since 2009, a commercial Primus plant at Dragon Steel's Taichung Works, Taiwan (see *Figure 6)* has been processing 100,000t/yr of EAF dust, with a proportion of residues from integrated steelmaking in the charged mix. The flexibility of the technology allows joint processing of dust, sludge and scales, with ordinary coal types serving as fuel. In parallel to the pre-reduction in the MHF, zinc is fumed out of the charge and separately extracted from the off-gases as ZnO via a quenching and filtering route. Avoided dumping cost and iron return are the fix parts of an economic equation, whilst income from slag and, especially, ZnO sales may vary depending on local and global market conditions. ▷

Fig 5 **Rotary hearth furnace of RedIron recycling plant**

Fig 6 **Primus dust recycling plant**

PLD (Paul Wurth – Lhoist de-oiling) is a new technology for de-oiling polluted by-products generated by rolling mills, mainly mill sludge and scales **[7]**. The patented process consists of volatilisation of oil by using quicklime and its controlled oxidation at low temperature. A specially designed MHF serves as the reactor which allows intimate mixing of oily material with lime, facilitating a slow and efficient de-oiling process. The output material is a dry, fluid powder of iron oxide with a residual oil content of less than 0.1%. A basic, industrial configuration would be a 25,000t/yr oily material processing capacity, but feasibilities have been calculated for up to 100,000t/yr so far. The return of relatively pure iron oxide, for instance to a sinter strand, and avoided dumping cost, are the economic factors proving the PLD technology.

CIROVAL™ is a new hydrometallurgy technology at the R&D stage for selective recycling of blast furnace sludge originating from the wet stage of top gas cleaning. It allows lixiviation of zinc and lead from the sludge, while simultaneously reducing iron loss thanks to fine-tuned control of reactions. This enables, first, high recovery yield of the iron-carbon matrix, which can be recycled to the blast furnace route. Second, it leads to production of concentrated zinc-lead cake with limited iron content, which can be reused by the non-ferrous industry. There is proven success from pilot tests with sludge from different blast furnaces. Full-scale industrial applications would result in maximised recycling and reduced dumping of critical material **[8]**.

CONCLUSIONS

For primary transformations of steelmaking, there are existing technologies for addressing today's challenges for energy-optimised, cost-efficient and environmentally compliant operations. These technologies have been proven at full industrial scale, or are close to full-scale application. Technology and plant-building companies like Paul Wurth are continuously innovating to make these technologies even more attractive as smart technologies which serve the industry's interest in combining profitable steelmaking and reduced environmental footprint. **MS**

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