IRON & STEEL MAKING FOR NICHES QUALITY PRODUCTS[1]

Christian Bartels v. Varnbüler[2]
Michael Lemperle[3]
H.-Jaan Rachner[3]

Abstract

In times of exploding costs for coke and quality scrap the hot metal producers look for alternative technologies that can produce liquid hot metal from cheap raw materials available at their location. The new OXYCUP® shaft furnace technology produces liquid hot metal, a smaller lance- and bottom blown converter and a degassing unit supplies steel to the caster for small production units up to approximately 500,000 tons per year. In contrast to other technologies OXYCUP® can process residues like zinc containing dusts and sludge e.g. from steel plants but also iron ore and DRI fines, HBI and even coarse lumps of pit scrap and skulls at the same time. Reduction of iron oxides contained in ore or residue fines is carried out with help of cheap carbon fines. Mixed with cement as a binder oxides and carbon fines are pressed to self-reducing "C-bricks" that can be charged into the shaft furnace. The OXYCUP® technology has proved its versatility by successful operating plants in Germany, Mexico and Japan. Coming projects are designed for Germany, China, India, Russia and Indonesia.

Key words: OXYCUP; Mini Mill; Waste; Horizontal caster.

PRODUÇÃO DE GUSA E AÇOS ESPECIAIS PARA PRODUTOS DE QUALIDADE

Resumo

No momento, com os altos custos para coque e sucata de qualidade, os produtores de gusa liquido estão procurando tecnologias alternativas para produção a partir de matérias primas baratas e disponíveis no local. A nova tecnologia de forno a cuba Oxycup® em conjunto com um pequeno convertedor com sopro por lança e pelo fundo e com um sistema de desgaseificação fornece aços para produtores com capacidades até 500.000 ton/ano. Diferentemente de outras tecnologias Oxycup® tem a capacidade de processar tanto residuos siderúrgicos, como por exemlo pós contendo zinco e lamas de aciaria, como também finos de minério de ferro e de redução direta, ferro briquetado a quente e até junto com grossos de cascão e sucatas. A redução dos oxidos de ferro contidos no minério é feita com finos de carbono baratos. Os finos metálicos e o carbono são misturados e prensados em forma de tijolos "C-bricks" autoredutores para serem carregados no forno. A tecnologia Oxycup® comprovou a sua versatilidade em operações de sucesso na Alemanha, México e Japão. Novos projetos estão em desenvolvimento na Alemanha, China, Índia, Rússia e Indonésia.

Palavras-chave: OXYCUP, mini mill, residuos siderúrgicos, lingotamento horizontal.

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2 *President, Kuettner GmbH & Co. KG, Essen, Germany*
3 *Vice-President, Kuettner GmbH & Co. KG, Essen, Germany*

INTRODUCTION

Dusts and sludge from steel plants rich in iron oxides and also ore fines can be processed after agglomeration in the OXYCUP® shaft furnace. This allows winning back hot metal from wastes for further treatment in an oxygen converter or as supplement liquid addition in an electric arc furnace respectively. Such OXYCUP® is extremely attractive for steel shops that are forced to handle their by-products for economic or legal reasons. For the integrated steel plants it has become most important to get rid of the capacity problems encountered with the sinter plant and blast furnace operation when by-products become a part of their charge.

In contrast to EAF and BF operation the OXYCUP® shaft furnace can easily process high amounts of zinc in the burden that may either originate from steel plant residuals or from automotive scrap. The lower price of such high zinc containing materials compared to clean scraps combined with the advantage of selling the zinc-enriched dust or filter cake to a zinc recovery plant strongly favors the economy. Also sponge iron from direct reduction plants can be melted to a large extent in an OXYCUP® shaft furnace.

Beside waste and by-product processing OXYCUP® can serve as the hot metal supplier for mini mills. Combined with converter, AOD/VOD and horizontal continuous caster the production of niche products is an economic alternative to electric melting.

1 OXYCUP® furnace

Figure 1 shows a section through the shaft of a long campaign OXYCUP® furnace. The upper part contains the charge receiving hopper and the annular gas exhaust chamber below. This arrangement keeps the furnace top smoke-free. The middle part serves for preheating the charge and finally for melting the iron and slag bearing constituents. The lower part contains the OXYCUP® hearth and the separator for iron and slag. In contrast to common blast furnace operation iron and slag are leaving the furnace continuously and may be collected in torpedo cars or ladles respectively.

The lower part is full of coke, the coke bed. Hot blast at 500°C to 620 °C and oxygen are blown through water cooled tuyeres and lances into the coke-bed to yield high temperatures of approximately 1900 to 2500 °C. At these temperatures superheating and carbonizing of liquid metal droplets occur sufficiently rapidly when in contact with the coke. The carbon pick-up is strongly determined by the height between the bottom of the hearth and the tuyere level which has to be considered in the furnace design. The hot gas leaving the coke bed provides the necessary heat for reducing the iron oxides in the C-bricks, melting the metallic charge and to preheat the charged materials in the gas counter-flow. The coke is burned to a mixture of CO and CO_2.

Depending on the composition of the by-products, coke quality, desired hot metal analysis, slag analysis and heat losses by tuyeres and shell cooling, 700 to 1200 m^3 hot blast and 50 to 200 m^3 of oxygen are required to burn 170 to 300 kg of coke per t of hot metal.

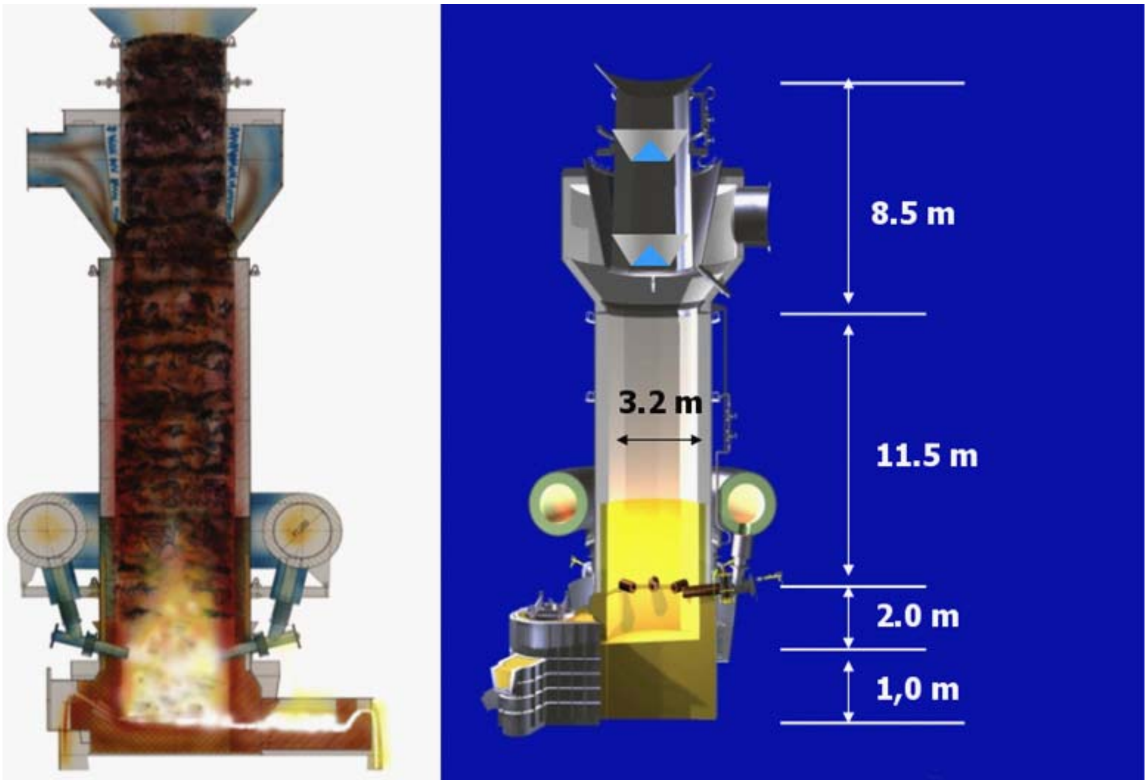

Figure 1: Long campaign OXYCUP® shaft furnace

2 Oxygen application

The application of oxygen either as enrichment of the blast or more effective as a beam via separate lances offers many advantages that in most of cases repays the expenditures for the equipment. In particular, when higher amounts of iron oxides are to be processed oxygen can sustain the temperatures in the coke bed that are necessary for a proper operation.

Figure 2 shows some of the most important parameters that determine the temperature within the coke bed. If temperatures of the liquid iron between 1450 and 1550 °C are to be achieved the coke bed temperature should be between 1780 and 1920 °C as denoted in the diagram. The pronounced effect of oxygen admission may be explained for the case of FeO in the burden.

Because the reduction of iron oxides is a heat consuming process the temperature of the coke bed will drop when such oxides are charged either from the top in the form of briquettes or when they are blown-in via the tuyeres. In the latter case additional heat is withdrawn from the coke bed for heating up the dust from ambient temperature to the actual coke bed temperature.

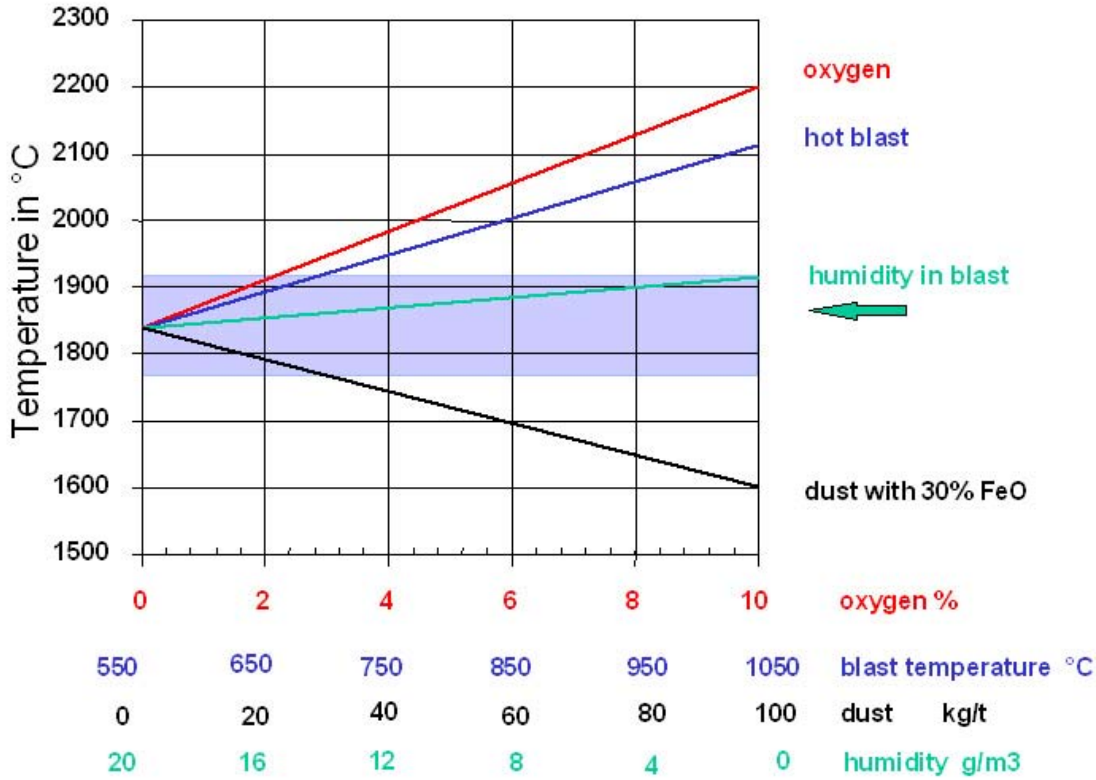

Figure 2: Temperatures in the coke bed

From the diagram it can be seen that blowing 100 kg/t_{Fe} dust with 30% FeO content will cause a drop in temperature of approximately 250 °C. Either a hot blast temperature of 1050 °C or an oxygen enrichment of 10% is required to compensate this.

It is quite obvious that high amounts of iron oxides are preferably processed with the use of oxygen injection rather than via extremely high hot blast temperatures. In some exceptional cases where low-cost electric power is available plasma generators may be used to heat up the blast. Of course, also the well known hot blast generation by Cowper stoves is possible and in particular first choice if existing equipment from thrown out blast furnaces is available. A recent development is the injection at supersonic speed that allows deep penetration of oxygen into the middle of the coke bed for a better temperature distribution.

3 Processing residuals

As an alternative to dust injection various agglomeration and briquetting methods have been developed. If wet residuals like filter cake from wet de-dusting systems are to be recycled compacting methods are best suited. However, in most of the cases a binder is required if stable briquettes are to be produced. Cement, sodium silicate, molasses and many other substances have been tried out to optimize strength and stability for the use in the OXYCUP®. [1]

High amounts of iron oxides can be processed in an OXYCUP® in form of self-reducing agglomerates. These agglomerates may contain residuals from steel plants or even iron ore fines. In all cases, the carbon necessary for the reduction of the oxides must be present inside such a C-brick.

In the compacted powder mixture of a C-brick, the consecutive reduction of FeOx and oxidation of carbon occur via the intermediate reaction products CO and CO_2, see Figure 3. All investigations indicate that the overall rate of reduction of the iron oxide is controlled primarily by the rate of oxidation of carbon in CO_2/CO mixture that prevails within the inter-particle pores.[2,3]

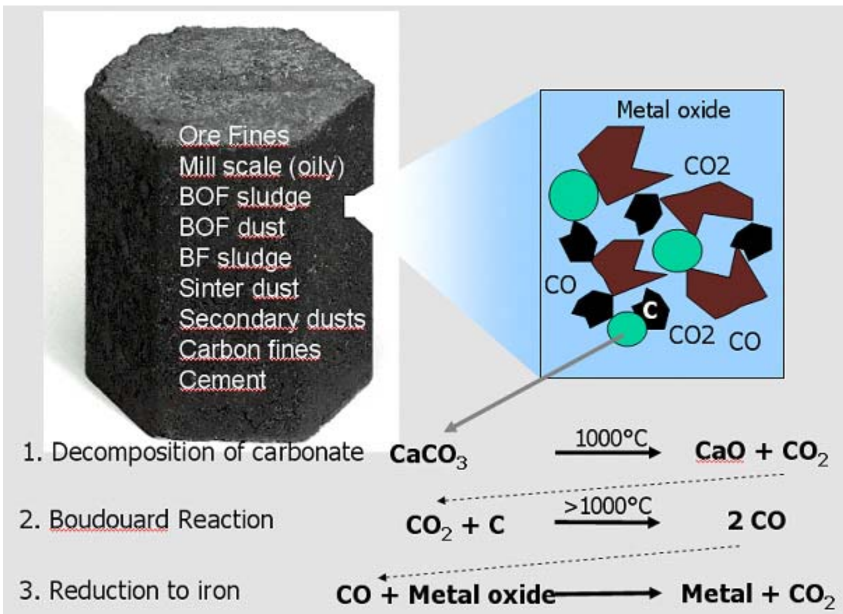

Figure 3: C-brick, possible iron carriers, sequence of reactions

The rate of oxidation of carbon with CO_2 is noticeable only above 1000 °C and fast at 1400°C.

The high reaction rates at high temperatures can only be used, however, if free access of the reaction gases to the carbon and iron oxide particles is maintained. Care has to be taken therefore that low melting compounds cannot form and plug the pores before the reduction of the FeO is completed. Exact analysis of the wastes and certain know-how is necessary to prepare the appropriate mixture.

4 C-brick production

The production facilities for C-bricks are adopted from the concrete stone production technique used worldwide. The different components of the C-brick as listed in the above picture are intensively mixed according to a pre-calculated recipe together with about 10% cement as a binder and carbon fines serving as reducing agent. The mixture also contains about 17% water being necessary for curing of the cement.

The prepared mixture is given into a bin on top of the brick press which fills a frame with moulds arranged on a wooden pallet. Punches lowering from above into the moulds assure the proper fill out. The essential compacting of the material in the moulds is then carried out by vibration.

Figure 4: Brick making machine with punches lifted above the moulds. Green bricks are pushed forward on their wooden pallets about every 20 seconds**.**

5 Brick design

According to the design of the OXYCUP® shaft furnace the C-bricks have an overall residence time of only approximately 1.5 h from charging to smelting. Because reduction of the iron oxides contained in the bricks is sluggish below 1000 °C and also practically stops when melting occurs at approximately 1450 °C the reduction has to be completed within 15 to 20 min. Many tests have proved that this short period is sufficient for the reduction of bricks to be completed in an OXYCUP® shaft. Size and shape of the bricks were investigated with respect to reduction and handling properties. It turned out, that rather big size bricks in the range of about 10 cm edge length led to even gas distribution and also showed a good reducibility in the furnace.

6 Brick handling

After leaving the press the C-brick laden pallets are pushed forward and get stacked up to 25 on top of each other in a collecting tower. After being filled a special multi-fork lift takes out the whole stack and transports it into curing hall where the C-bricks stay between 2 and 3 days for hardening. The cured bricks are taken out again by the multi-fork lift which charges the entire pallet stack into a collecting tower that discharges the pallets individually on an idler belt for transportation to the brick discharge drum. This rotating device turns the pallets and discharges the bricks onto a conveyor that fills the brick silo. The empty pallets are returned to the brick press. This principle is shown in following pictures.

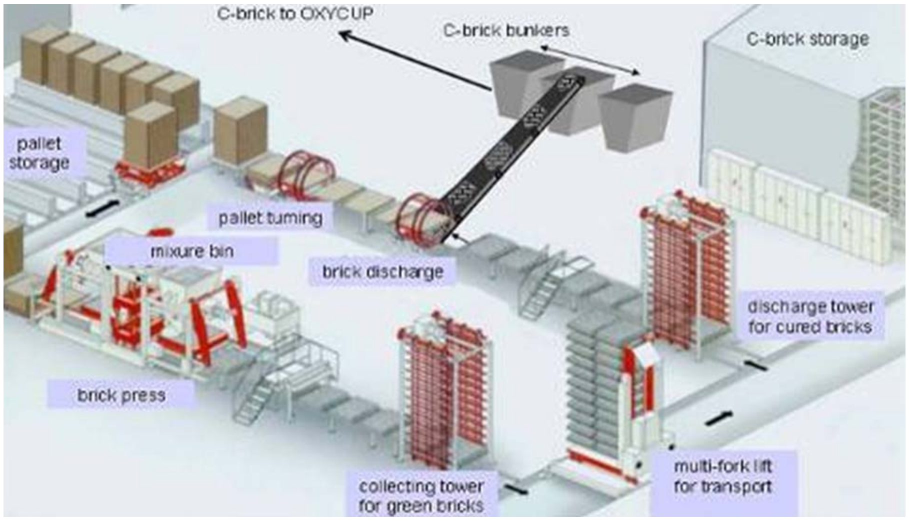

Figure 5: C-brick press with brick handling and pallet cycle

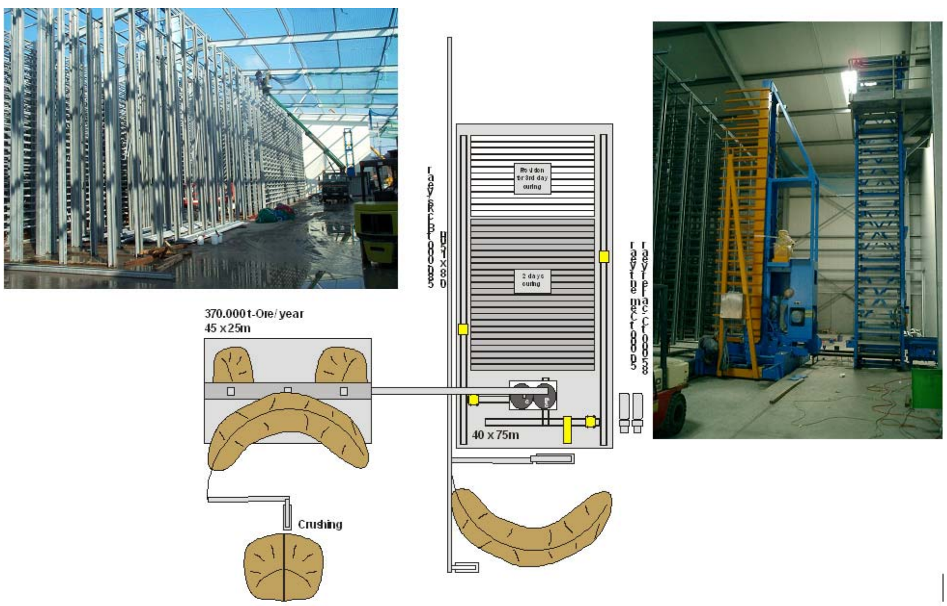

Figure 6: C-brick curing hall during erection (left), material handling (middle) and multi-fork lift with collecting tower (right)

7 CO-generation and "zero waste" concept

For integrated steel works OXYCUP® will not only process dusts and sludge residues but also skulls and pit scrap. Many of these substances cause problems when being recycled to the sinter plant, blast furnace and BOF shops because of their grain size or unknown analysis with respect to the iron content [4]. It has turned out that it is very advantageous to run the core processes sinter plant, BF and BOF with virgin material only and process all waste and by-product materials in OXYCUP®.

Because of its outstanding properties with respect to its high temperatures in the hearth and melting zone the OXYCUP® shaft furnace can also process up to 70% HBI (hot briquetted iron from direct reduction plants) or approximately 30% DRI (sponge iron). These materials still contain some percent of iron oxides and also the gangue of the ore but have the advantage of being free from metallic impurities that may impair the hot metal qualities. A mixture of scrap with such virgin materials can overcome quality problems that often arise with cheap scrap grades.

Beside iron and slag OXYCUP® produces a valuable top gas of about 4200 kJ/m3 that can be used for power generation. About 10 MW power can be produced by co-generation of an OXYCUP® plant for 200,000 t/a of residues.

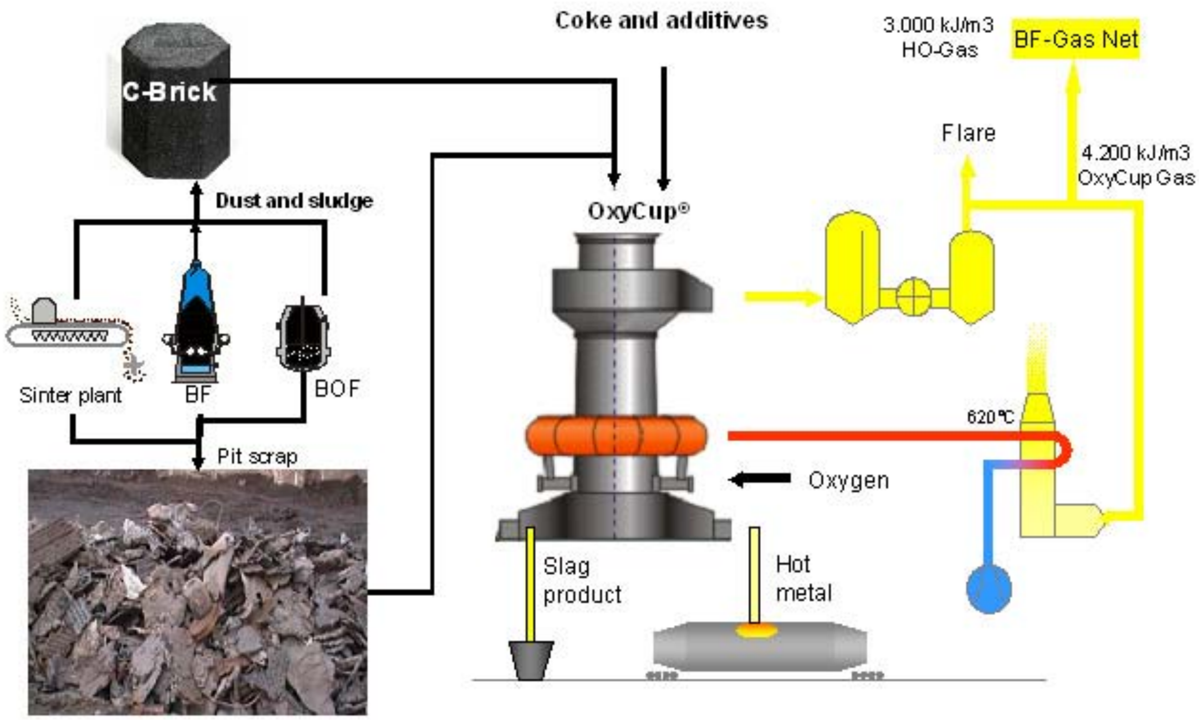

Figure 7: By-products from different sources as input materials for OXYCUP®. As products: hot metal, slag and medium calorific gas

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8 OXYCUP® plants of industrial scale

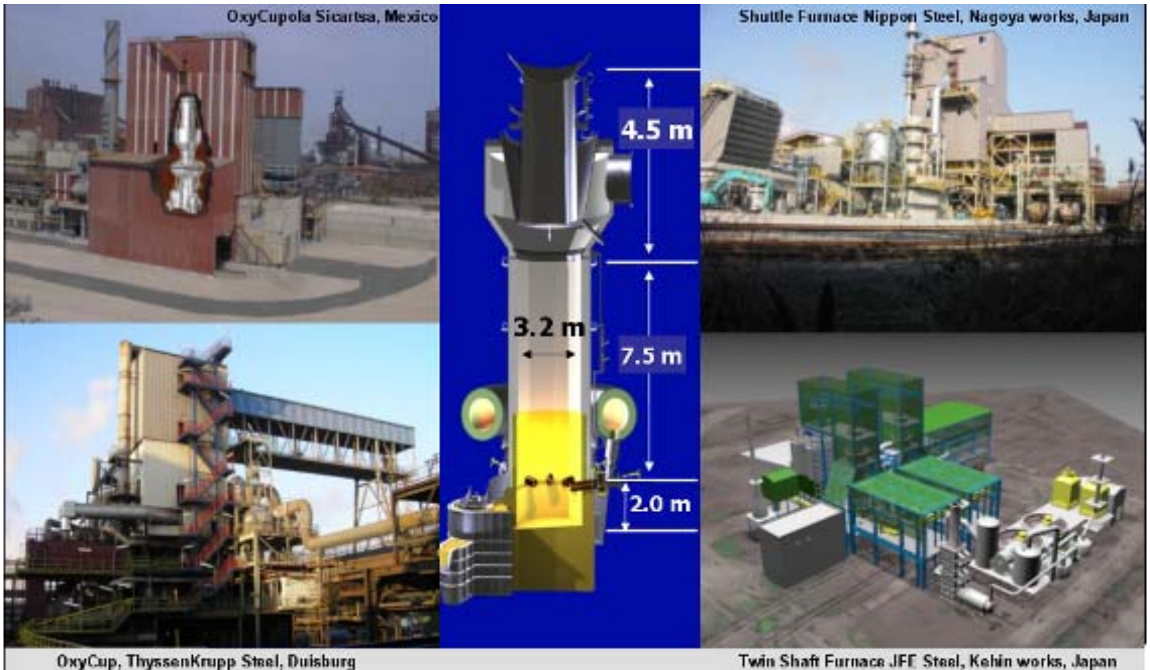

Figure 8: OXYCUP® plants world wide

The OXYCUP® technology has proved its versatility by successful operating plants within integrated steel works in Germany, Mexico and Japan. Coming projects are designed for Germany, India, Russia, Indonesia and China.

9 Mini mill steel production based on OXYCUP® technology

For steel productions up to 500,000 t/yr an OXYCUP® shaft furnace is well suited as hot metal source. Combined with a converter and a horizontal continuous caster a variety of different steel qualities can be produced in multiple dimensions. Supplemental AOD or VOD converter can be employed for special qualities. The required building space is low for a horizontal continuous caster which lowers investment cost.

Top and bottom blowing is applied in the KOC (Küttner Oxygen Converter). The “Two Slag” operation results in excellent silicon and phosphorus removal with the first slag and sulphur and carbon removal with the second slag treatment. Alloying in the converter is also possible to a certain extent.

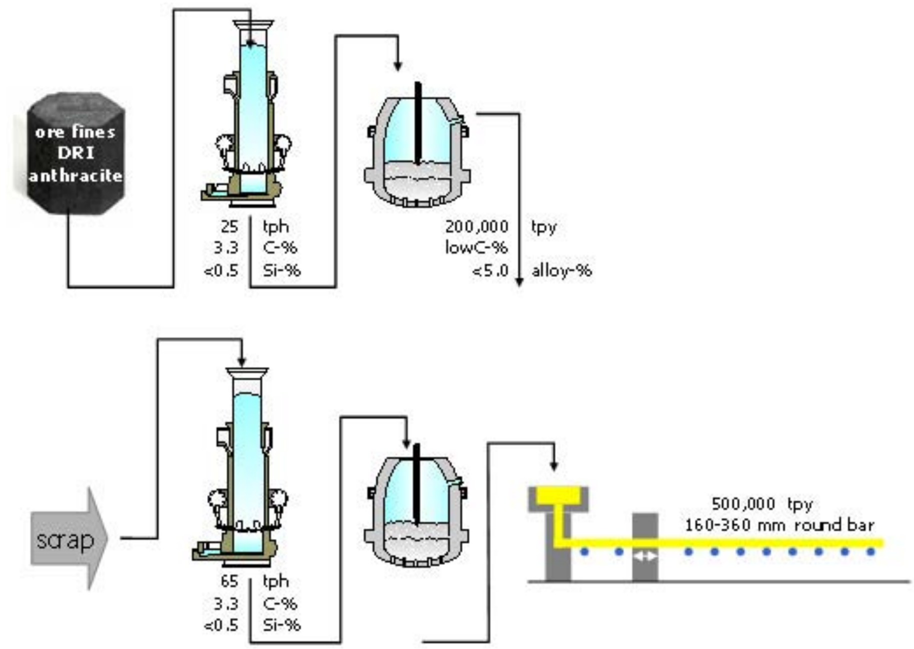

Figure 9: OXYCUP® shaft furnace mini mill concepts: Based on C-bricks from ore and DRI fines (top) or based on scrap melting.

Figure 10 depicts a horizontal continuous caster of a small steel mill in Germany.

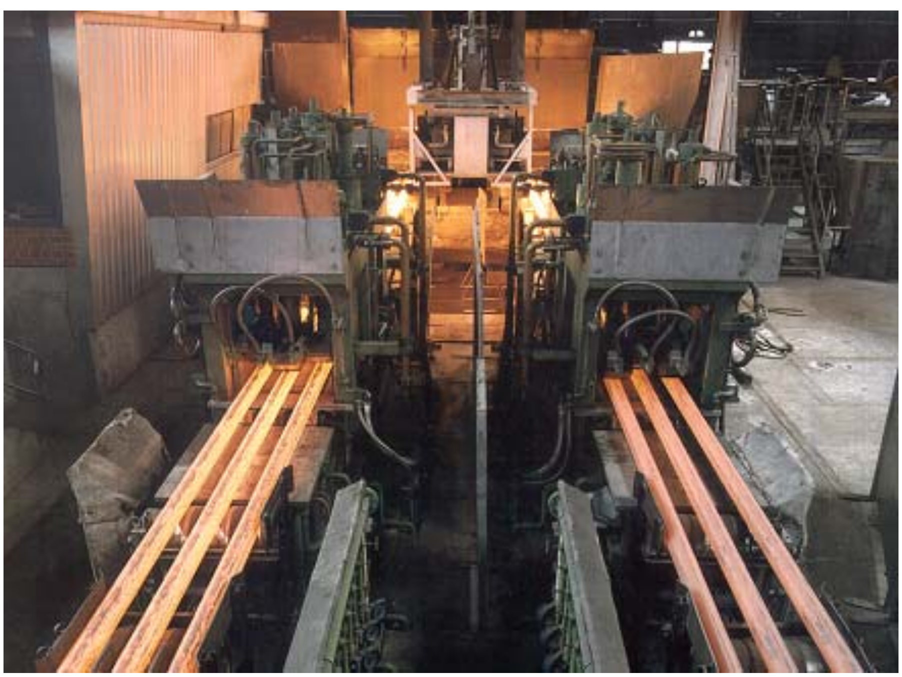

Figure 10: Horizontal continuous caster for mini mills

10 Conclusion

The shaft furnace and OXYCUP® technology has developed to a proven technology for the conversion of wastes into hot metal and has been used as a reliable hot metal supplier in integrated steel plants [5]. In contrast to other waste processing technologies OXYCUP® can also handle coarse pit scrap and delivers a liquid hot metal product that can be directly used in the converter. Due to successful processing of dusts and sludge new applications for OXYCUP® also focus on the production of hot metal from iron ore fines and from iron sands. For mini mills a shaft furnace or OXYCUP® can be the basis for steel production. In these cases a horizontal caster allows a flexible production at low costs.

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