Smelter for low-grade DRI melting for a low-carbon steel industry

With high-grade iron ore demand increasing, the availability and cost of low-grade iron ore reveals an immense potential to reduce emissions and maintain production. Producers can successfully decrease their emissions while maintaining production rates by utilizing a smelter. This is a new solution for the final reduction and melting of low-grade direct reduced iron. Additionally, the cost-effectiveness of low-grade iron ore reduction takes advantage of increasing amounts of low-grade iron ore on the market. Producers can reduce their environmental impact, contribute to the circular economy, and maintain capacity by replacing the blast furnace with a direct reduction plant combined with a smelter.

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MEETING DEMAND AND REDUCING EMISSIONS

The steel industry is experiencing increased pressure to reduce carbon emissions after contributing about 7% of all global CO_2 emissions **[1]**. With pressure rising, the industry has begun a revolutionary transformation impacting all aspects of steel production. However, transforming production routes to limit their environmental impact is perhaps one of the most difficult challenges facing the industry, as adopting new technologies involves a reasonable risk. Yet, with global demand for steel set to rise, an effective means to reduce environmental impact and increase yield could be exceptionally lucrative **[2]**.

Today, the integrated route, i.e., blast furnace (BF) and basic oxygen furnace (BOF) route – is still the dominant steelmaking method worldwide, making up more than 70% of global steel production **[3]**. Simultaneously, this production route, particularly the blast furnace, is responsible for the largest share of carbon emissions from raw material to finished product. Producers can avoid the most significant contributor to carbon emissions in steelmaking by replacing the blast furnace with direct reduction processes. Thus, using direct reduction plants combined with an electric arc furnace (EAF) offers the highest potential for emissions reduction. However, while the direct reduction of high-grade iron ore is suitable for direct application in an EAF, low-grade ore can typically generate high amounts of slag, making it inefficient for use in an EAF **[4]**.

LOW-GRADE IRON ORE REDUCTION

The coming decades might see more than 200 new DRI plants and increased adoption of EAFs. Simultaneously, these changes in the industry will increase market demand for high-grade iron ore to produce direct reduced iron (DRI) and hot briquetted iron (HBI). The increased demand will directly impact the market for DR-grade iron ore, with only a small percentage coming close to an iron (Fe) content of 67% or more **[5]**. A clear challenge when comparing the blast furnace to direct reduction is that even with iron ore beneficiation technologies to increase the ferrous content of the ore, the blast furnace is much more flexible when it comes to processing low-grade iron ore. Thankfully, applying a two-step process using a smelter plus the BOF to melt and refine low-grade ore processed in a direct reduction process, can improve the environmental impact of steel production and sustain yield.

The smelter intervenes in the steelmaking process by melting and reducing low-grade iron ore hot-charged from the direct reduction process. Adapting to various input materials, the smelter can manage low-grade pellets and hot compacted iron, e.g., from the MIDREX direct reduction process or direct reduced iron from hydrogen-based directly reduced iron ore fines, made using HYFOR technology. The technological benefit of the smelter rests in its ability to adjust the carbon level of the output material. The design of the smelter also considered specific characteristics to mimic the type of slag produced by the blast furnace.

Figure 1 illustrates the flexibility of the smelter in combination with varying direct reduction routes for low-grade iron ore, including hydrogen-based direct reduction routes.

DESIGNED FOR REDUCED ENVIRONMENTAL IMPACT

Separating valuable hot metal from the slag allows the smelter to contribute to the circular economy by producing slag similar to the blast furnace, which has become widely used in the cement industry **[6]**. The basicity of the slag from the Smelter can also be adjusted to achieve high levels of glass content, which is ideal for such applications. The smelter can also take advantage of advanced

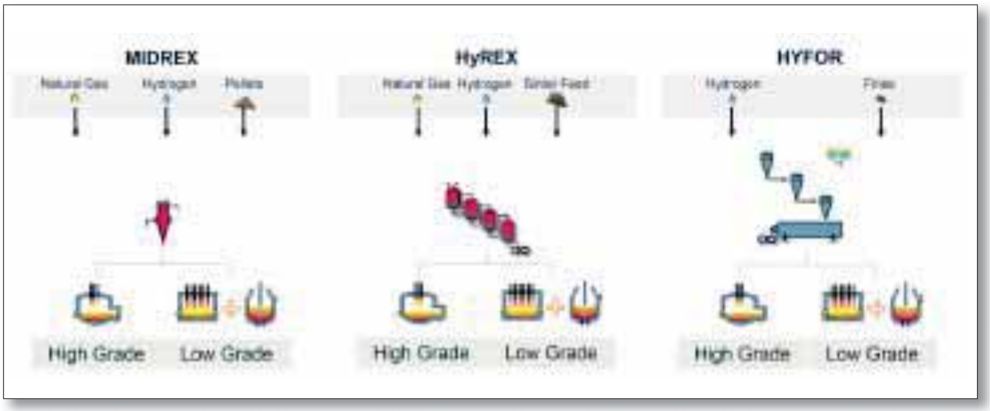

Fig 1 **Integration of a smelter in various production routes**

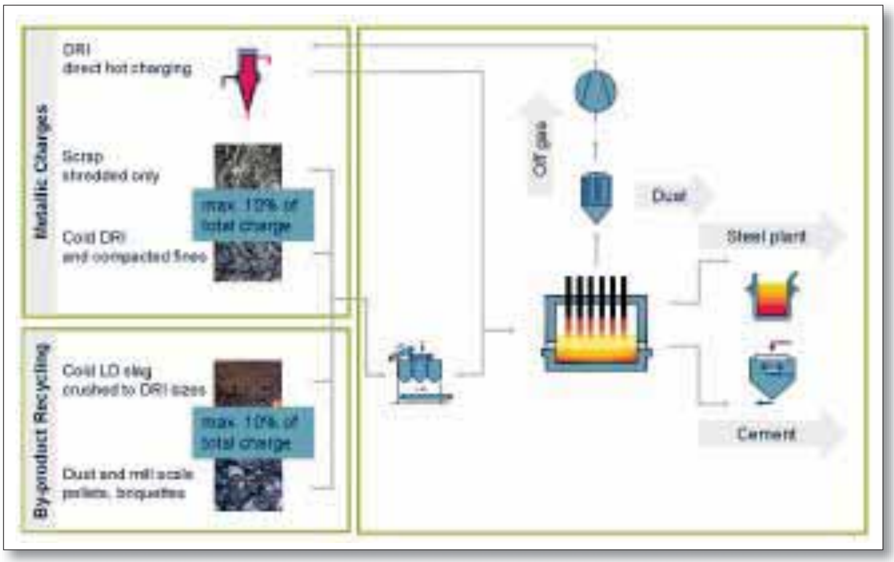

Fig 2 **Opportunity for recycling of materials through the charge**

solutions for dry slag granulation. For the recycling of various materials, charges of scrap and recycled by-products can be incorporated into the hot-charged DRI. From there the slag by-product can be sent to the cement industry and other technologies can intervene to reduce the environmental impact further. This is shown in *Figure 2*. Beyond slag recycling, the air-tight operation makes it optimal for recycling iron and iron oxide-containing by-products, e.g., dust, mill scale, or slag in a smelter. Powered by six-in-line electrodes, the rectangular furnace can reach 1.5Mt of DRI charged annually.

MAINTAINING CAPACITY AND ADAPTING TO THE BASIC OXYGEN FURNACE

Adopting a smelter to reduce low-grade iron ore presents various benefits and readily integrates with plants operating BOFs. Capable of processing 1.5Mt of DRI, the smelter can easily adjust to existing plant infrastructure and logistics, and parallel smelters can also be implemented to increase capacity. The design also ensures a high yield even if the slag amount is very high, thanks to the long setting time. While implementation presents the challenge of additional operational expenditure, i.e., the operation of the smelter unit and BOF, cost analysis demonstrates the effective low energy costs and the ability to take advantage of the market price for low-grade iron ore, make the smelter an ideal transformational technology.

Finally, the smelter is designed to adapt to an existing integrated plant. With a BOF on site, minor adaptations mean the smelter can be incorporated into the current design. The only real change is the blowing scheme of the BOF, which sees improved blowing time due to lower carbon and silicon levels in the liquid hot metal from the smelter. Despite certain factors impacting the scrap rate of the smelter and BOF, the overall benefit of reduced emissions and improved yield reveal the advantage of smelter adoption. Moreover, as producers invest and implement the smelter, regular operation of the blast furnace may continue thanks to the smelter's flexible sizing and engineering.

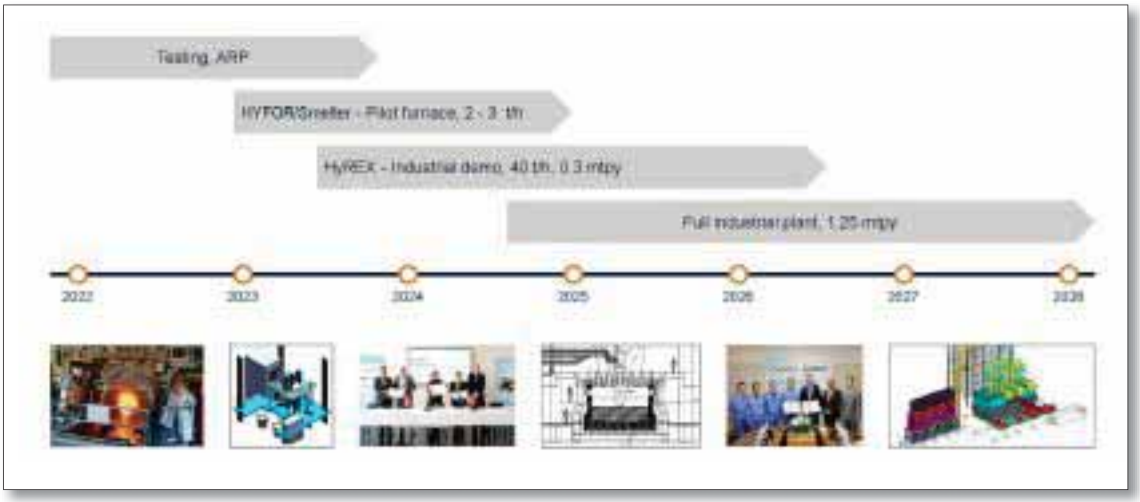

Fig 3 **Development timeline**

CONCLUSION

Applying a smelter in integrated steelworks and combining it with a BOF offers steel producers a clear alternative toward the transition to high-grade iron ore DRI and the operation of an EAF. With a carbon-neutral steel industry in mind, the smelter is also designed to integrate with direct reduction plants operating at 100% hydrogen, including Hydrogen-Based Fine Ore Reduction (HYFOR). Currently in development, an industrial prototype plant in Linz is in the initial phases that will effectively combine the production of green hydrogen with the direct reduction of iron ore fines in a HYFOR plant and smelter to produce liquid hot metal with extremely low carbon emissions (*Figure 3*) **[7]**.

Capable of handling hot DRI, the smelter operates seamlessly with direct reduction plants and can deliver reduced liquid hot metal to converters in operation. Combining itself with hydrogen-based DRI and with the potential for being powered by renewables, the smelter could see reductions in carbon emissions and approach carbon neutrality.

Both HYFOR and HyREX hydrogen-based technologies are making headway in combination with the smelter toward an industrial scale plant before 2030. With the transformation of the industry well underway, the implementation of these technologies is vital to a sustainable steel industry. MS

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