LATEST ADVANCES IN DIRECT REDUCTION TO SERVE MINIMILLS AND INTEGRATED MILLS

BY

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SYNOPSIS

For more than 45 years HYL has developed technologies designed to improve Hylsa's steelmaking competitiveness and productivity. The HYL Process has been improved over generations and the current status of the technology, the HYL ZR (or Self-reforming) Process, was developed to allow reduction of iron ores in a shaft reactor without external gas reforming equipment. The HYTEMP® System developed to transport hot, high carbon DRI directly to the EAF meltshop, has been successfully operating since 1998. This process scheme has the ability to produce high carbon DRI or High Carbide Iron (HCI®), which allows producers to obtain maximum benefits of carbon in the steel making process, while for merchant sale of the product, eliminating the need for costly briquetting equipment thanks to its highly improved stability.

Additionally, based on the ZR process scheme, HYL and Ferrostaal AG have redesigned the basic HYL DR plant with the goal of achieving a DR Mini-Module, which falls within the reach of steel producing companies while supplying, on-site, the DRI requirements to meet the desired steel quality and allowing steel production to be less dependent on prevailing market fluctuations and conditions relevant to the metallics.

On the other hand, the main forthcoming factors of relevant importance for integrated steelworks are: limited supply and increasing prices of coke and scrap, and environmental restrictions related to CO_2 emissions, which could be of economical importance due to regulations/trading aspects envisioned in the Kyoto Protocol. By modifying the current trend of using spent gases from integrated facilities for power generation, these issues can be overcome by using these gases for more value-added DRI production while reducing fossil fuels consumption and decreasing CO_2 emissions. The use of available energies from integrated steelworks for production of DRI and consequently for production of liquid steel (LSt), as well as energy optimisation is also analysed in this paper.

Keywords: Direct Reduction (DR), Direct Reduced Iron (DRI), Self-reforming (ZR), high carbide iron (HCI), coke oven gas (COG), hot metal (HM), hot rolled coils (HRC), powdered coal injection (PCI).

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1. The HYL ZR Process

The HYL ZR Process (Figure 1) is a major step in reducing the size and improving the efficiency of direct reduction plants. Reducing gases are generated by in-situ in the reduction reactor, feeding natural gas as make-up to the reducing gas circuit and injecting oxygen at the inlet of the reactor. Compared to a conventional DR plant including reformer, in addition to lower operating/maintenance costs and higher DRI quality, the total investment for a ZR plant is typically 10 to 15% lower.

A remarkable advantage of this process scheme is the wider flexibility for DRI carburisation, which allows attaining carbon levels up to 5.5%, due to the improved carburising potential of the gases inside the reactor, which allow for the production primarily of iron carbide.

For the production of high quality DRI, i.e. 94% metallisation, 4% carbon and discharged at 700°C, the energy consumption is 2,25 to 2,40 Gcal/ton DRI as natural gas and 60 to 80 kWh/ton DRI as electricity, with a remarkable low iron ore consumption of 1,35 to 1,40 t/t DRI, mainly due to high operating pressure.

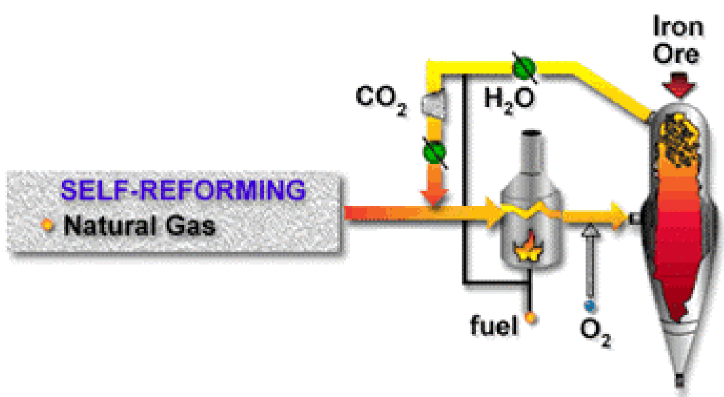

Figure 1. HYL ZR or Self-Reforming Process Diagram

This plant configuration has been successfully operated since 1998 with the HYL DR 4M plant and was also recently incorporated (in 2001) in the 3M5 plant [4], both at Hylsa's Flat Products Division in Monterrey.

Of course, HYL plants can also use the conventional steam-natural gas reforming equipment, which has long characterized the process. Other reducing agents such as coke oven gas (COG), hydrogen, gases from coal, petcoke and similar fossil fuels gasification and coke-oven gas, among others, are also potential sources of reducing gas depending on the particular situation and availability.

2. Description of the HYL ZR Process Scheme

The HYL ZR Process is based on the reduction of iron ores with reducing gases, which are generated from partial combustion and in-situ reforming of natural gas or COG, taking advantage of the catalytic effect of the metallic iron inside the reduction reactor [2]. The plant can be designed for production of cold DRI or hot DRI for direct charging to a melting facility. The general scheme of the HYL DR process is shown in Figure 2.

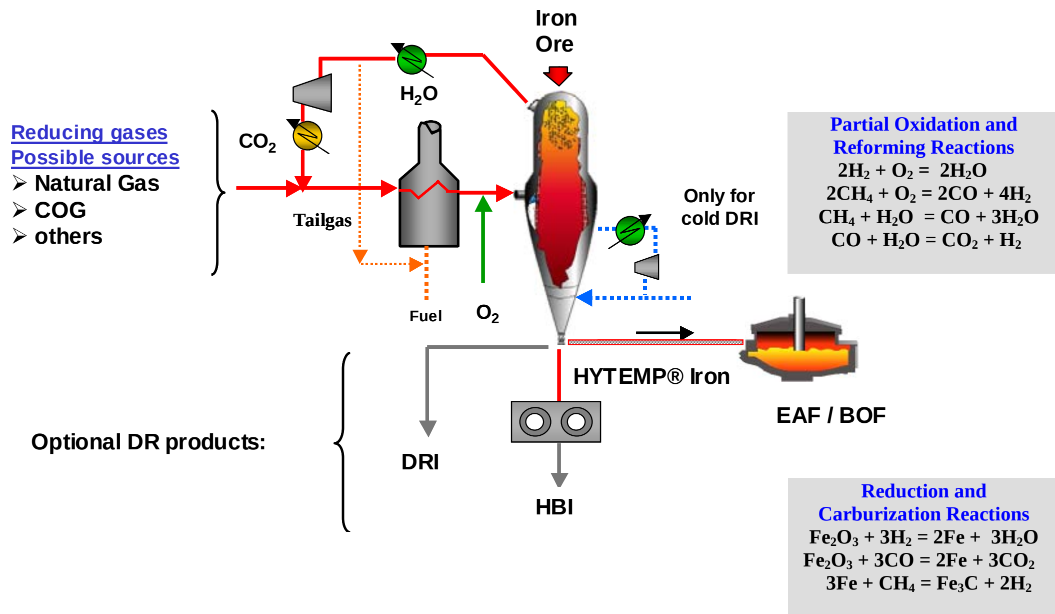

Figure 2. HYL ZR Process Flowsheet

The process scheme includes the following features which, when combined, eliminate the need for a reducing gas generation system:

<u>Partial combustion of the reducing gas:</u> Due to current constraints of alloys materials to increase gas temperature from heater above 1000°C, partial combustion of methane (CH_4, in natural gas or COG) with oxygen provides the additional energy, which is required for reforming in-situ, and for the carburisation of the metallic iron.

<u>“In-situ“ reforming in the lower part of the reactor’s reduction zone:</u> Once in contact with the solid inside the reactor, further methane reforming in-situ takes place due to the catalytic effect of the metallic iron.

<u>Adjustable composition of the reducing gas:</u> The level of metallisation and carbon can be controlled independently by adjusting main process parameters and the gas composition.

Although the reducing gas temperature at the reactor inlet is very high – above 1000°C, due to the endothermic behaviour of the combined chemical reactions taking place inside the reactor, the resulting temperature at the reduction zone is below the potential condition for material cluster formation.

The reactor operates at elevated pressure (6 bar, absolute), allowing a high reactor productivity of about 10 t/h x m² and minimising dust losses through top gas carry-over. This is reflected in low iron ore consumption, which allows keeping the operating cost low.

One of the inherent characteristics of the HYL process scheme and of high importance for this application is the selective elimination of both by-products generated from the reduction process; water (H_2O) and specifically carbon dioxide (CO_2), which are eliminated through top gas scrubbing and CO_2 removal systems, respectively.

The main characteristics of possible DR products, which can be produced in an HYL DR facility, are presented in Figure 3.

Item/use	DRI on-site consumption	HYTEMP® Iron direct feed to EAF	HBI overseas export
Metallisation	**93–95**	**93–95**	**93–95**
Carbon	**2.5 - 5**	**2.5 - 5**	**1 - 2**
Temperature (°C)	**40**	**> 600**	**40**
Bulk density (t/m^3)	**1.6**	**1.6**	**2.5**
App. density (t/m^3)	**3.2**	**3.2**	**5.0**
Nominal size (mm)	**6–13**	**6–13**	**110x60x30**

Figure 3. DR Products Typical Characteristics

3. DRI quality – HYL High Carbide Iron (HCI)

Carbon in the DRI, mostly as iron carbide (Fe_3C), is derived mainly from CH_4 and in less extent from CO. The level of carbon is adjusted by controlling the reducing gas composition and/or oxygen injection. Most of the carbon in DRI currently being produced in the HYL ZR scheme is in the form of Fe_3C (see Figure 4).

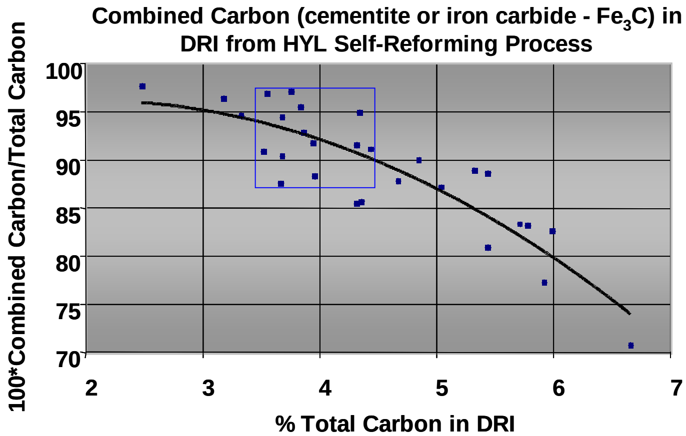

Figure 4. Combined Carbon in DRI

DRI produced with the ZR scheme is characterized by a higher stability than DRI typically obtained in other DR process schemes. The reason for this is the high cementite or Fe_3C content, which inhibits the re-oxidation of metallic iron in contact with air. Most of the Carbon in the DRI is present as Fe_3C. For a carbon content of 4% approximately 95% is present as Fe_3C. In general every 1% of combined carbon corresponds to 13.5% of Fe_3C. A DRI with 4% Carbon contains more than 50% of Fe_3C.

The high percentage of Fe_3C in the DRI of the 4M plant makes the product very stable. This highly improved product has been registered as High Carbide Iron or HCI to distinguish it from typical reduced iron products and although it is necessary to follow proper handling procedures, it is evident that the product is now more stable for shipping and handling

HYL High-Carbide DRI vs. Conventional DRI

HYL ran extensive tests to determine whether the combined carbon in DRI was a factor in improving product stability over that of conventional DRI, whether produced by HYL plants or other process technologies.

Currently, there are two plants operating under the HYL ZR process scheme: the Hylsa Monterrey 3M5 plant produces cold-discharge DRI, and the Hylsa Monterrey 4M plant produces hot-discharge DRI, using the HYTEMP System for hot DRI transport to the meltshop, and cold DRI is also produced via an external cooler [4]. To the end of December 2003, the accumulated production of high-carbon DRI (94% metallisation, carbon range from 3,5 – 4,2%) from both Monterrey HYL Process plants was more than 5,0 million tonnes.

The stability of High-Carbide Iron has been proven in specific tests that were performed for DRI being produced at the 3M5 plant, before and after its conversion to the ZR scheme. These test results are included in Figures 5, 6 and 7. Both products were tested in contact with air, in contact with air and water and with salty water, to simulate stability behaviour in contact with seawater. The high-carbide iron produced in the HYL ZR process proved to be significantly more stable due to the protective effect of the combined carbon in the product. Results of the test with salty water, as per Figure 7, are of relevant importance due to the low risks for HCI overseas transportation.

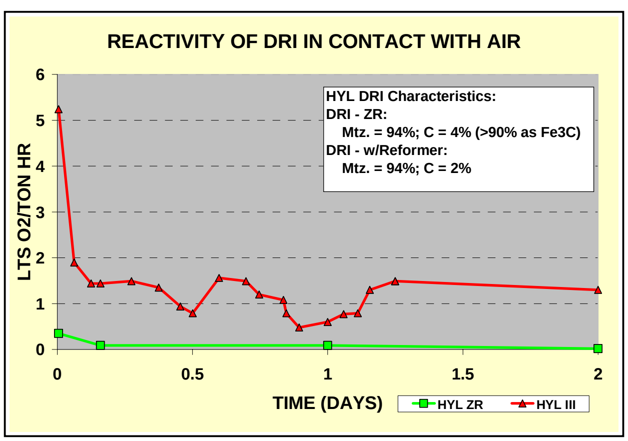

Figure 5. DRI Reactivity with Air

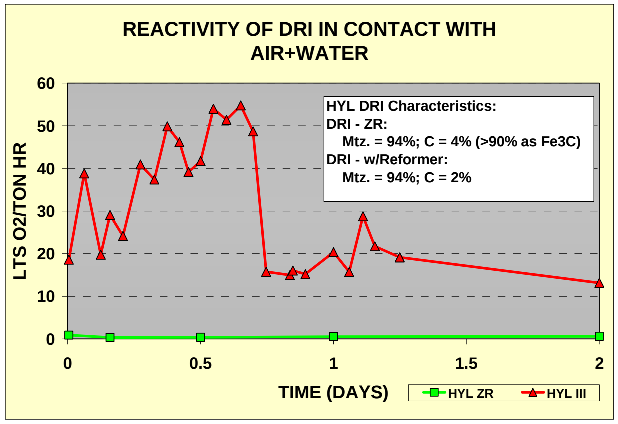

Figure 6. DRI Reactivity with Water

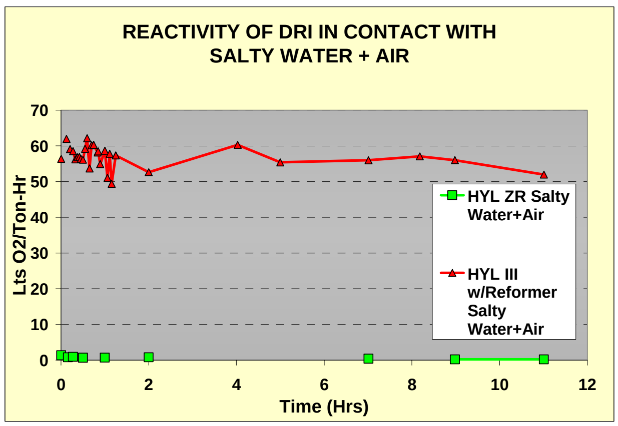

Figure 7. DRI Reactivity with Salty Water

4. Use of high-carbon hot DRI in Hylsa's EAF.

Benefits of high-carbon hot DRI in meltshop operations has been demonstrated in Hylsa's EAF. Before start-up of operations of the 4M DR plant, only cold DRI to EAF was entirely produced in 2M5 and 3M5 DR plants. Typical DRI quality from these plants was of 93-94% metallisation and about 2.2% carbon. After 4M plant start-up, hot DRI quality has been 94% metallisation and 4% carbon.

The EAF #2 is a DC-type with capacity of 135 t Liquid Steel (LS)/heat and average active power is 110 MW. The figures included below correspond to EAF operation with different percentages of DRI in the metallic charge, keeping constant the metallisation at 94% for various levels of carbon. Oxygen injection is 25 Nm^3/tLS for 2.2% carbon DRI and 42 Nm^3/tLS for 4% carbon DRI.

High-Carbon DRI

In general, carbon in the DRI provides chemical energy input to the EAF, decreasing electric power requirements. As compared to other sources of carbon injection, cementite in DRI is characterised by a higher recovery yield in the EAF. Besides, EAF's quality carbon is normally available at higher cost than the carbon obtained from natural gas in DRI. Adequate oxygen injection is required to take advantage of this carbon.

Impact of DRI carbon in the EAF is presented in Figure 8. Graphite injection is about 12 kg/tLS for DRI with 2,2% carbon and 0,5 kg/tLS for DRI with 4.0% carbon. For these operating conditions, the change from 2,2% to 4% carbon in cold DRI represents a decrease of 11-kg graphite and 58-kWh/tLS. This power saving is a result of the replacement of graphite by cementite related to yield and heat reaction. In terms of transformation costs, incorporation of high-carbon DRI has been reflected in more than 4-$US/tLS, for Hylsa's particular conditions.

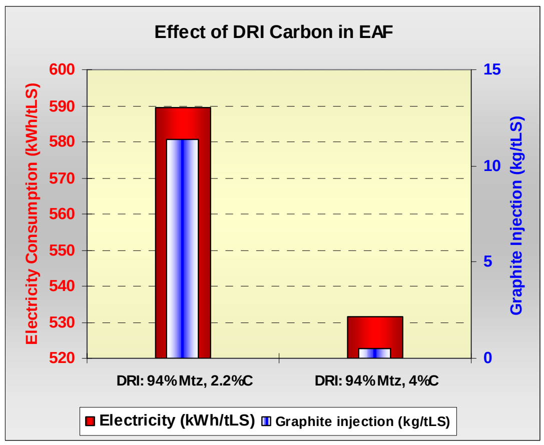

Figure 8. Effect of DRI Carbon in EAF Performance

High-Carbon Hot DRI

Production of high-carbon, high-temperature DRI is reflected in important savings in the meltshop. However, to include the overall system, it is necessary to determine additional costs in the DR plant when producing hot DRI with high carbon content.

Changes of DRI quality and temperature imply variations of energy consumption in the DR plant, mainly related to natural gas and oxygen. The sensitivity analysis for two levels of carbon (2,2% and 4%) in DRI at different feeding temperature to EAF is shown in Figures 9. For these cases, DRI metallisation is constant at 94%.

On the other hand, hot DRI feed provides additional sensible heat to the EAF, reducing power consumption and tap-to-tap time, which are reflected in productivity increase. Direct feed of hot DRI in Hylsa's meltshop is carried out through HYTEMP® system. Comparative analysis based on results of hot charging to EAF #2 related to electricity consumption are presented in Figure 10 while the effect on power on time –consequently on productivity- are shown in Figure 11.

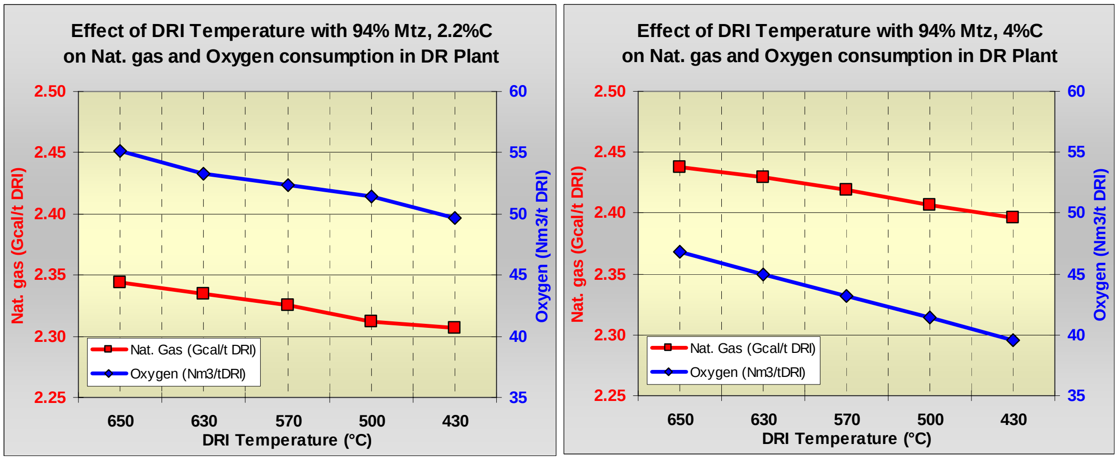

Figure 9. Effect of DRI Temperature
on Nat. gas and Oxygen Consumption in DR Plant

Data for different percentages of DRI with 94% metallisation and various carbon levels has been included. Difference between cold DRI with 2,2% C (Ref. 1) and hot DRI at 500°C with 4% C (Ref. 2), for 100% charge to the EAF are: a decrease of about 180-kWh/tLS and about 12 min on power on time, which may represent over 25% potential productivity increase.

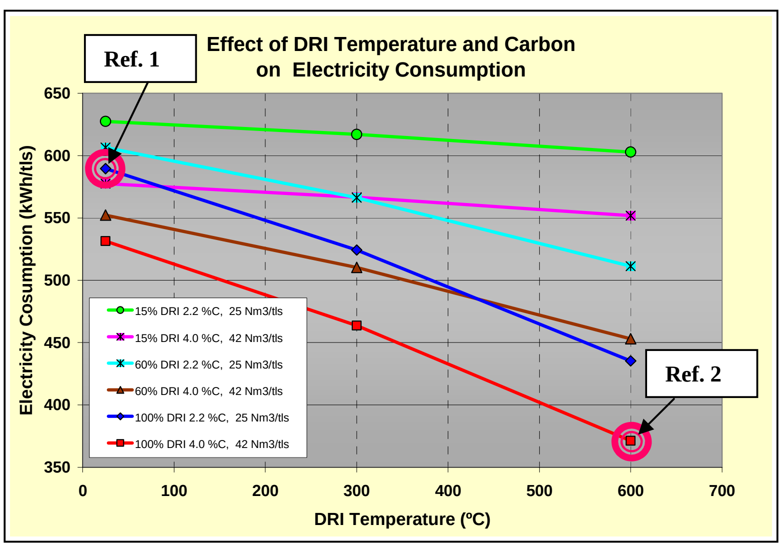

Figure 10. Effect of DRI Temperature and Carbon on
Electricity Consumption in EAF

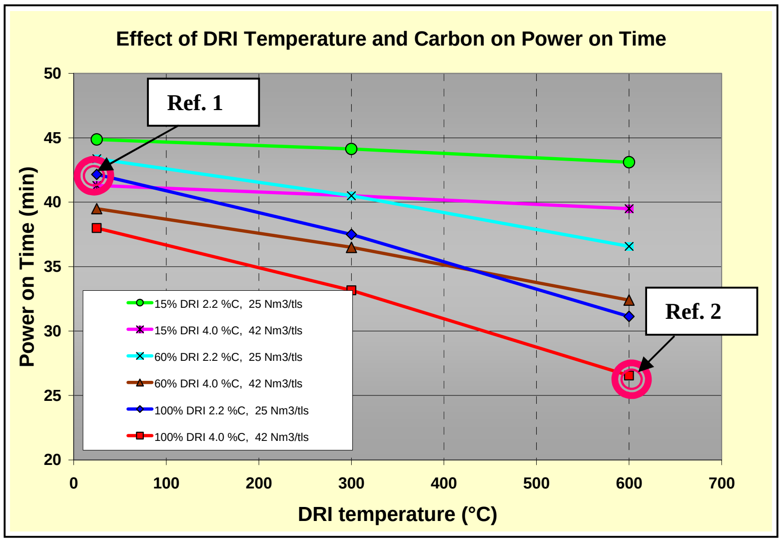

Figure 11. Effect of DRI Temperature and Carbon on Power on Time in EAF

5. Cost Analysis

Based on the above results, indicative cost analysis is presented in Table 1.

Effect of DRI Carbon and Temperature on Liq. Steel Production Cost

Metallization	**%**		**94**		**94**		**94**		**94**	
Carbon	**%**		**2.2**		**4**		**2.2**		**4**	
Temperature	**ºC**		**25**		**25**		**600**		**600**	
	Unit	Price US$/unit	Consump. Unit/tls	Cost US$/tLS	Consump. Unit/tls	Cost US$/tLS	Consump. Unit/tls	Cost US$/tLS	Consump. Unit/tls	Cost US$/tLS
DR Plant										
Iron ore pellets	t	40	0.97	38.6	0.97	38.6	0.97	38.6	0.97	38.6
Lump ore	t	32	0.41	13.2	0.41	13.2	0.41	13.2	0.41	13.2
Natural gas	Gcal	7.9	2.31	18.3	2.41	19.1	2.33	18.5	2.43	19.3
Oxygen	Nm^3	0.05	50	2.5	41	2.1	53	2.7	45	2.3
Electricity	kWh	0.035	60	2.1	60	2.1	60	2.1	60	2.1
Water	m^3	0.02	1.3	0.0	1.3	0.0	1.3	0.0	1.3	0.0
Other consumables	US$			1.2		1.2		1.2		1.2
Maintenance				3.0		3.0		3.0		3.0
Labour	m-h	7	0.17	1.19	0.17	1.19	0.17	1.19	0.17	1.19
Total DRI cost				**80.2**		**80.6**		**80.6**		**80.9**
EAF										
DRI charge	kg	0.0802	1195.9	96.0						
	kg	0.0806			1217.7	98.1				
	kg	0.0806					1195.9	96.3		
	kg	0.0809							1217.7	98.6
Electricity	kWh	0.035	589.6	20.6	531.4	18.6	435.4	15.2	371.2	13.0
Magnesite	kg	0.39	1.66	0.6	1.5	0.6	1.2	0.5	1.0	0.4
Graphite	kg	0.15	11.35	1.7	0.5	0.1	11.4	1.7	0.5	0.1
Lime	kg	0.05	10.96	0.5	10.9	0.5	11.0	0.5	10.9	0.5
Dolo-lime	kg	0.06	40.81	2.4	40.2	2.4	40.8	2.4	40.2	2.4
Oxygen	Nm^3	0.05	24.99	1.2	42.0	2.1	25.0	1.2	42.0	2.1
Electrodes	kg	2.63	1.57	4.1	1.4	3.7	1.2	3.1	1.0	2.6
Refractories & WCP	US$			2.1		1.9		1.5		1.3
Maintenance	US$			4.0		4.0		4.0		4.0
Direct labour	US$			0.9		0.9		0.9		0.9
Total LS cost	**US$**			**134.2**		**132.9**		**127.4**		**125.9**
Annual Capacity	**ktLS/yr**		**839**		**903**		**1,031**		**1,140**	

Table 1. Cost Analysis for DR and EAF
for different levels of Carbon and Temperature

Although typical cost figures for consumables have been considered, the analysis can be adapted to local cost structure. It can be observed that additional energy cost in the DR facility, required to obtain higher carbon, higher temperature DRI, is almost negligible as compared to the costs savings in the EAF. For 100% DRI charge, impact of carbon, from 2,2% to 4%, is about 1,5 US$/t LS while an increase of temperature from ambient to 600°C, is about 7 US$/t LS. Besides, the potential productivity increase of liquid steel, up to 36%, is the most important benefit in the EAF, which should be credited when applicable.

6. HYL DR Mini-Module

The HYL Mini-Module [2] is a 0.3 –0.5 Mtpy plant with a significantly lower investment cost than the typical DR plant, and which offers shorter construction time to reach full production. The plant is a simple yet technologically advanced design and produces high quality, high carbon DRI at production cost, which is attractive to the quality EAF steel producer.

Advantages of a DR Mini-Module in a Minimill

For steel mills, a DRI integrated facility presents a number of advantages: DRI would be available on-site, allowing steel production to be less dependent on prevailing market fluctuations and conditions relevant to the metallics. Liquid steel quality is improved by the availability of DRI, thus enabling the minimill to meet any finished product specification. Additionally, the steel mill would benefit from flexibility in DRI quality in terms of metallisation and carbon, depending on the particular steelmaker requirements. There are also implicit cost benefits, since the cost of briquetting is avoided when buying HBI. Furthermore, the DRI production rate can be tailored to meet the metallics requirements of the minimill, thereby avoiding financial participation and off-take commitments in external high capacity DRI plants.

Besides the advantages for a minimill of an integrated DR plant, the HYL Mini-Module concept presents features, which are reflected in benefits associated to both operating and investment costs. Among these features, the following are the most important:

- Small plant size. The main hurdle to integrate DR plants in minimills have been the investment cost associated with conventional (high capacity) DR plants, which makes the installation of DR plants in general not attractive for minimills. With this in mind, the concept was developed an optimised for a low investment cost DR plant with a capacity of 0.3 – 0.5 Mtpy. This range of plant size was selected to cover most cases for the required amount of virgin metallics.

- Low investment cost. Adapting the latest developments and improvements of the HYL Technology based on the ZR process scheme has significantly reduced the specific capital investment.

- Optimised process design. Specific optimisation of process parameters, as a result of the industrial operation of the Hylsa 4M DR plant, has been incorporated in the design of the HYL Mini-Module.

- Prefabricated equipment (skid-mounted, modular design). There has always been an economic compromise between prefabricated equipment and erection time. For big plants, to transport prefabricated equipment is not normally the best option. However, for this small plant, there is better economical attractiveness to have most systems and equipment skid-mounted thus, reducing erection time.

- Short erection time. As mentioned above, this is the result of modular design and prefabrication of most equipment.

- Compact, optimised layout. The required area for a Mini-Module of 0.45 Mtpy (Figure 12) is only 52.5 m x 70.0 m, which can be easily implemented in existing facilities.

- Synergy by using existing and/or common utilities/services. Most of the existing infrastructure and utilities; i.e. oxygen plant, water systems, etc., can be utilised and/or modified to serve the Mini-Module. In such cases, additional investment can be reduced.

Other inherent characteristics of the HYL Mini-Module are related to plant simplicity. The simple and compact plant allows for low maintenance cost and minimum manpower requirements. The plant is also easy to operate and has low operating costs, basically due to its flexibility in processing a wide range of cheaper iron ores (pellets/lumps), and the uniformity of the finished DRI product.

Design basis for the HYL Mini-Module

The Mini-Module is designed for cold DRI production in order to simplify plant design and to reduce additional investment costs due to briquetting. However, depending on the particular needs of a minimill and the overall cost structure and economic benefits, hot DRI production and hot charging to meltshop through HYTEMP® System can be also incorporated.

Simplifications implemented in the HYL Mini-Module are already in place and/or proven in other HYL DR industrial plants in operation. In this regard, there are no technological risks.

Figure 12. HYL Mini-Module. General Plant Arrangement

Optimised Investment Cost

In general, specific investment cost of small DR plants is higher than that of big plants. The main target of the economical investigation has been to decrease the specific investment cost of the small DR plant to a cost level that should be comparable or even lower than the price structure of plants designed for more than 1.5 Mtpy. As the result of such efforts, budgetary figures for a 450,000 t/a HYL Mini-Module are in the range of US$145–150 /t per annual capacity.

7. Incorporation of a DR plant in Integrated Steelworks

The major gaseous fuel by-products, which are recovered in integrated steel works, are: blast furnace gases (BFG), coke oven gases (COG) and basic oxygen furnace gases (BOFG). There is the possibility of using these surplus gases for other than electrical power generation, specifically for production of DRI [3].

As shown in Figure 13, for a balanced conventional integrated steel mill, about 32% of the fossil primary energy is surplus gas, which is mainly used for power generation. Specific figures are referred to units per tonne of hot metal (HM) and hot rolled coils (HRC). The total amount of electric power, which can be produced (assuming 36% efficiency), is in the range of 560 kWh/t HRC. About 220 kWh/t HRC are used for in-plant requirements and the remaining 340 kWh/t HRC has to be exported.

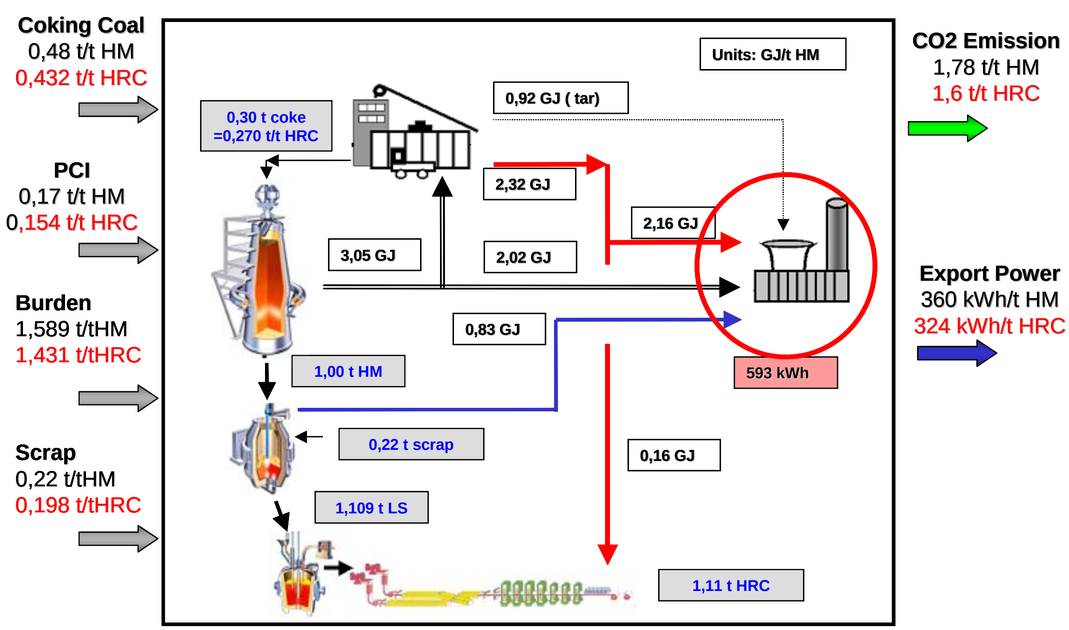

Figure 13: Overall Balance for Integrated Steelwork based on HRC-Production

Figure 14 gives an overview of this idea, simply replacing the power plant (Figure 13) by a DR plant. The figure shows DRI production, energy balance and CO_2 emissions.

The maximum production of DRI in this balanced integrated steelwork is in the range of 380 kg / t LS.

For this application, spent gases from the integrated steel mill are sent to the DR plant and split as follows:

- COG and BOFG are totally used as process gas for DRI production.
- Required amount of BFG is used as fuel for reducing gas heating and steam generation.

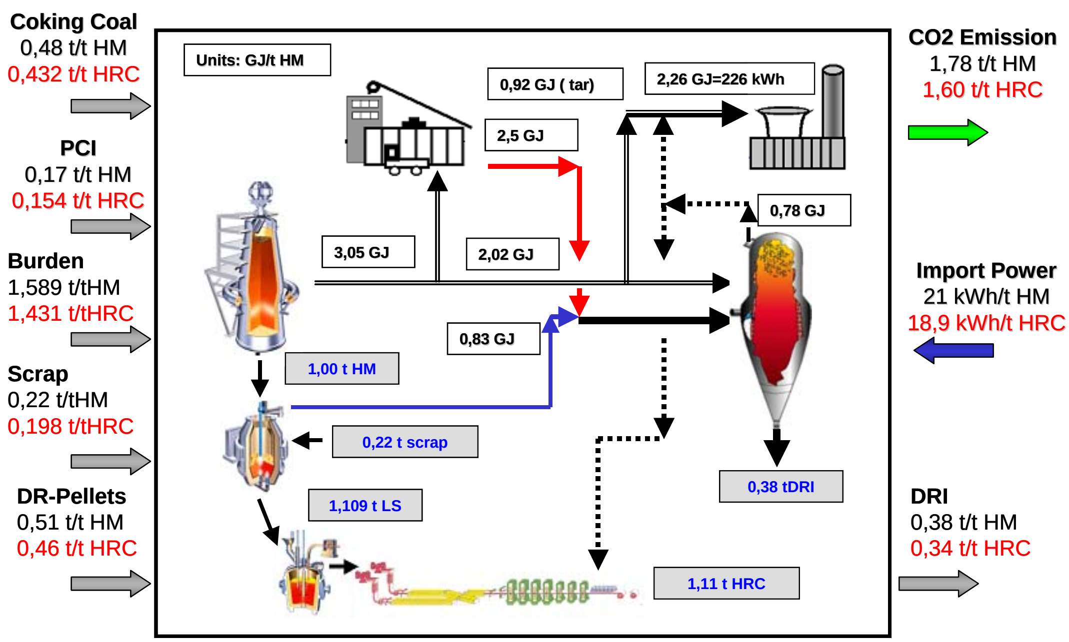

Figure 10: Overall Balance with integrated DR-Plant

8. Use of DRI in integrated Steelwork

In an integrated steelwork the DRI can be used either in the BF or in the BOF. As an example the two following cases are analysed:

Case 1: Charge of cold DRI to the blast furnace

Basis for this analysis are:

- BF using 300 kg of coke and 170 kg of powdered coal injection (PCI)/t HM.

- DRI production, as per available COG and BOFG is about 380 kg/t HM, with 94% metallisation and 4 % carbon.

For this conditions cold DRI is fed to the BF. For this analysis, the same liquid steel production rate has been kept. The main influencing parameters are:

- PCI consumption

- Oxygen consumption
- Amount of top gas
- Burden

For this case the main target is reduction of environmental impact due to a decrease of specific coal (PCI) consumption and CO_2 emissions by lowering PCI consumption. There is a reduction of about 70% of PCI/t HM and a potential decrease of CO_2 emission of about 28% less, considering the selective elimination from the DR plant, which should be delivered / disposed for other purposes than venting.

Influence of DRI/HBI feed to the BF has been reported in previous works performed in various facilities worldwide [3]. In general, most studies agree in an increase of 6 and 7 % production increase with 100 kg DRI/t HM, using the same coke and PCI consumption rate.

Case 2: Charge of DRI to BOF

An alternate possibility for higher liquid steel production is to feed the DRI into an BOF. For this case, only hot DRI is fed to the BOF.

There is a maximum possible crude steel production of about 1,384 t/t HM, as compared to conventional-scrap based case of 1,20 t/t HM. About 0,18 t LS (or 15,3%) is the production increase.

The cost of surplus gases from integrated steelworks (used for electrical power generation) has to be based on the price of steam coal for power generation. Table 2 shows a comparison of scrap based and hot DRI based production of liquid steel. The difference of about 21 US$ /t LS is mainly related to the scrap price, which is assumed to be in the range of 150 US$ / t. Nevertheless, to compete with the steel price made of DRI, the scrap price shall be about 60 US$/t.

Processing in BOF			Scrap as coolant		hot DRI as Coolant	
	unit	US$ / unit	unit/ t LSt	US$ / t LSt	unit/ t LSt	US$ / t LSt
Metallic Input						
Hot Metal	t	137,0	**0,83**	113,8	**0,72**	99,1
own scrap	t	150,0	0,00	0,0	0,00	0,0
import scrap	t	150,0	0,24	36,2	0,00	0,0
DRI (without capital cost)	t	77,0	0,00	0,0	0,36	27,8
Total metalic Input			1,07	**150,0**	1,08	**126,8**
melting processing						
alloys	kg	0,950	7,0	6,7	7,0	6,7
lime	kg	0,075	63,0	4,7	76,0	5,7
oxygen	Nm3	0,039	47,0	1,8	57,0	2,2
el.power	kWh	0,0400	70,0	2,8	70,0	2,8
others processing				5,0		5,0
Slag-handling	kg	0,015	116,0	1,7	147,0	2,2
Total melting				**22,7**		**24,6**
bonus for BOFG	GJ	1,5000	0,65	-0,98	0,83	-1,25
Total liquid steel cost				171,8		150,2

Table 2. Comparison of cost for liquid steel

Optional Case: DRI sale

In the worst case, if there were no possibility for using DRI in the mill, the simplest approach would be to sell it to steel plants with EAF.

9. Conclusions

The HYL ZR process has the flexibility to produce cold and/or hot High Carbide Iron, which allows producers to obtain maximum benefits of temperature and carbon in the steel making process, while for merchant sale of the product (cold DRI), eliminating the need for costly briquetting equipment thanks to its highly improved stability.

The concept of an HYL Mini-Module offers a unique possibility for steel mills to have a DRI integrated facility, with inherent benefits related to less dependency on metallics market fluctuations in terms of price and availability, and enabling the minimill to meet any steel product specification. The small DR module has higher flexibility for processing wider range of pellets and lumps available with no technological risks, since it is based on the successfully proven HYL ZR technology, in operation at industrial scale since 1998.

For the incorporation of a DR plant in an integrated steelworks there are various possibilities, depending on the prevailing situation of the integrated mill. A specific and detailed investigation will depend on the particular plant arrangement and economical conditions of existing integrated mills. Main benefits are:

- Decrease of fossil fuel consumption for HM production and CO_2 emissions.
- Potential for increase up to 21% of hot metal production keeping the same specific production figures.
- Increase of liquid steel production through BOF by about 15% using hot DRI as coolant.
- Potential increase of about 38% of liquid steel by installing DR-EAF facilities.

10. References

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