Operating results with hot DRI charge at Emirates Steel Industries

The use of 90% hot DRI, 10% cold DRI as the charge materials for a UHP 150t EAF with carbon-oxygen injection is demonstrating excellent energy efficiencies and plant productivity. When 100% hot-charged DRI becomes available shortly, productivity will further increase to 220tls/hr, tap-to-tap time will reduce to 41mins and electricity consumption will decrease to 380kWh/tls.

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In the past few decades the importance of DRI as a substitute for scrap has increased significantly. A recent example of the use of 100% DRI charge is the 150t UHP EAF FastArc™ at the Emirates Steel Industries (ESI) site in Mussafah Industrial Area, Abu Dhabi. The complex consists of a 1.6 Mt/yr direct reduction (DR) plant, 1.4Mt/yr steelmaking and casting plant, 0.62Mt/yr high-speed bar mill and 0.48Mt/yr high-speed wire rod mill.

EAF FEATURES

The split shell AC furnace operates on a 90% hot (600°C) DRI, 10% cold DRI charge, which is continuously fed via the 5th hole from the HYTEMP tower (see *Figure 1*). The EAF maintains a hot heel of 50t and has a rated tap weight of 150t liquid steel. Nominal productivity target is 196tls/hr with a tap-to-tap time of 46mins. The main geometrical data of the EAF are shown in *Table 1*.

One of the key factors in the EAF design is the location of the DRI feeding point with respect to the off-gas 4th hole. It was placed far enough from the off-gas elbow to minimise the loss of DRI fines in the fume treatment plant (FTP). For this reason the DRI entrance is on the slag door side of the furnace. The cross-section of the 4th hole was designed to reduce the off-gas speed below 30m/s.

Electricals The EAF transformer has a rated apparent power of 130 + 20% MVA and allows selection of 18 different tap positions for the best combination of arc voltage, arc current and power factor during process stages. The furnace secondary circuit is designed for a maximum current of 80kA. The main electrical data are summarised in *Table 2*.

The maximum active power applied is in the range 112-114MW, with a secondary current of 74-75kA and a specific power of 0.75MW/tls. This value can be considered one of the highest when compared with other furnaces melting DRI in amounts greater than 70%.

FastArc™ injection technology The injection system has been conceived with three kinds of injectors, each with

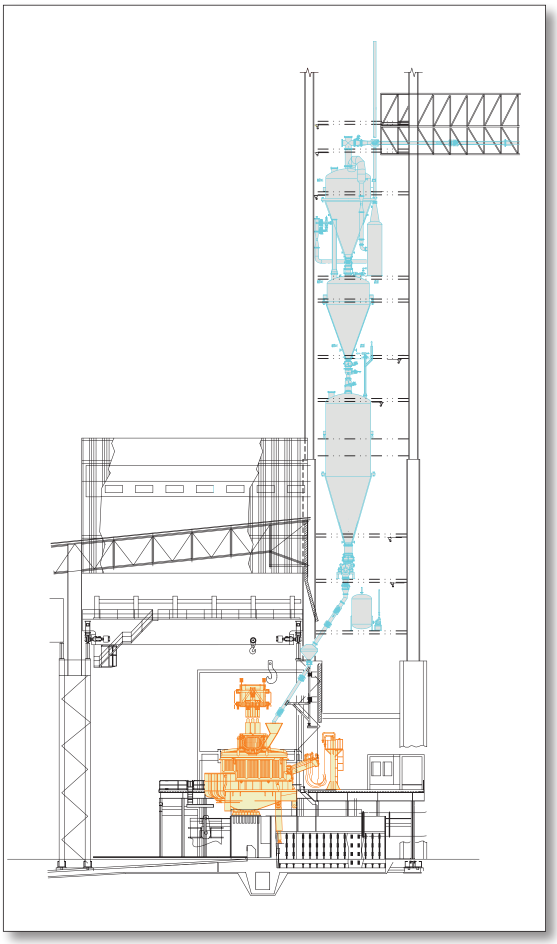

Fig 1 **EAF and HYTEMP DRI tower**

Item (diameter)	
Lower shell	7.0m
Electrode	710mm
Pitch circle	1,400mm

Table1 **Main furnace dimensions**

Item	Value
EAF transformer rated power, MVA	130
Overload, %	20
Frequency, Hz	50
Primary voltage, kV	33
Secondary voltage range, V	1,250–650
Secondary voltage at full power, V	1,250–1,120
SVC rated power, MVAr	170
Series reactor rated reactance, ohm	1.3

Table 2 **Main electrical data**

Module	Oxygen flow rate, Nm^3/h	Material feed rate, kg/ min
Oxygen jet 1-2-3-4-5	2,200	–
Carbon jet 1-2-3	150	15–30
Carbon injector	–	15–30

Table 3 **EAF injection system**

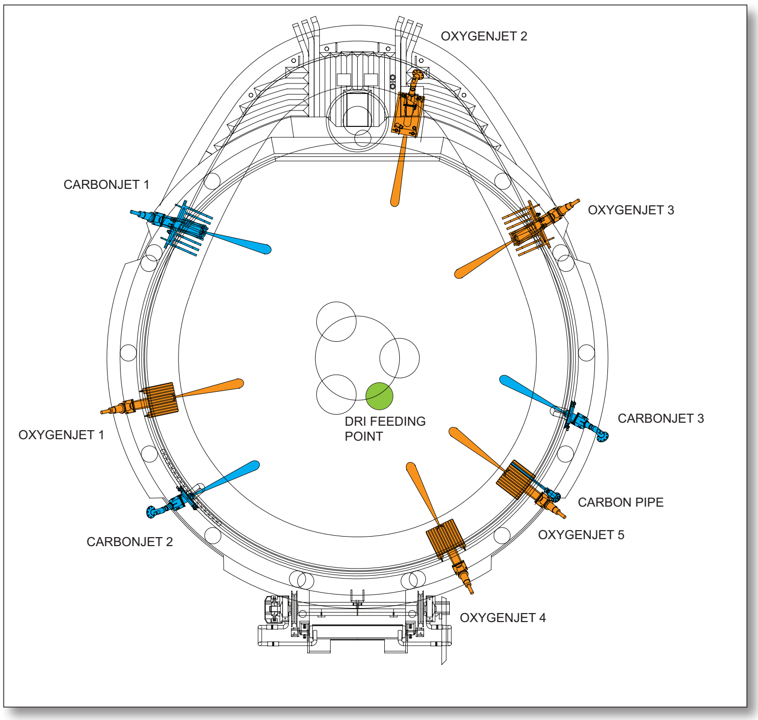

Fig 2 **Oxygen and carbon injector layout**

its own function, to achieve the best possible performance, as shown in *Table 3*.

Figure 2 shows installed injectors. The layout promotes maximum stirring effect in the region of the DRI addition point and to provide a uniform chemical input around the furnace circumference, improving thermal balance and avoiding cold spots. Carbon injectors are placed in the proximity of the oxygen injectors to promote slag foaming and to protect refractory hot spots from arc radiation.

PROCESS DESCRIPTION

DRI characteristics The main characteristics of the DRI are summarised in *Table 4*, the material analysis taken from the sampling bin during a 24-hour period.

Melting procedure *Figure 3* shows the detailed melting profile used for a 10% cold DRI, 90% hot DRI charge. The DRI feed rate is increased progressively through the heat starting from an initial value of 2,000kg/min and ramping up to the maximum value of 5,800kg/min after 13mins of power-on. Thanks to the excellent degree of metallisation, the balanced amount of carbon and the high reactivity of the high temperature pellets, very good foaming slag is achieved from the beginning of melting just after the DRI comes into contact with the oxidised hot heel.

NB: during the first 6mins the tap hole is filled with sand, the slag door breast is cleaned, and any other fettling or gunning is performed.

After 4mins from power-on, the maximum transformer tap is selected, reaching a typical maximum power in the range 100–108MW. This is even more relevant if we consider the refractory wear index (RWI), applied during the main phase of DRI feeding. The parameter reaches 230–235kWV/cm^2 for 75% of the power-on time without negative impact on the life of the refractory or the water-cooled panels. The DRI specific feed rate is 55kg/min/MW.

OPERATIONAL RESULTS

Thanks to increased utilisation of chemical energy by means of the DANARC injection system with Modules technology and the high power transformer, the furnace has achieved very fast DRI melting rates, equating to a productivity of 200tls/hr, well above the guaranteed value, and with power-on times of 35mins.

Consumptions Specific consumptions from 26 heats indicated in *Table 5* were recorded during commissioning. These results were achieved thanks to the excellent quality of the DRI in terms of metallisation and its 2.1% C. If we compare the results recorded with the utilisation of 90% of hot DRI at 600°C (column A), with 100% cold DRI charge (column B), there is a reduction of the

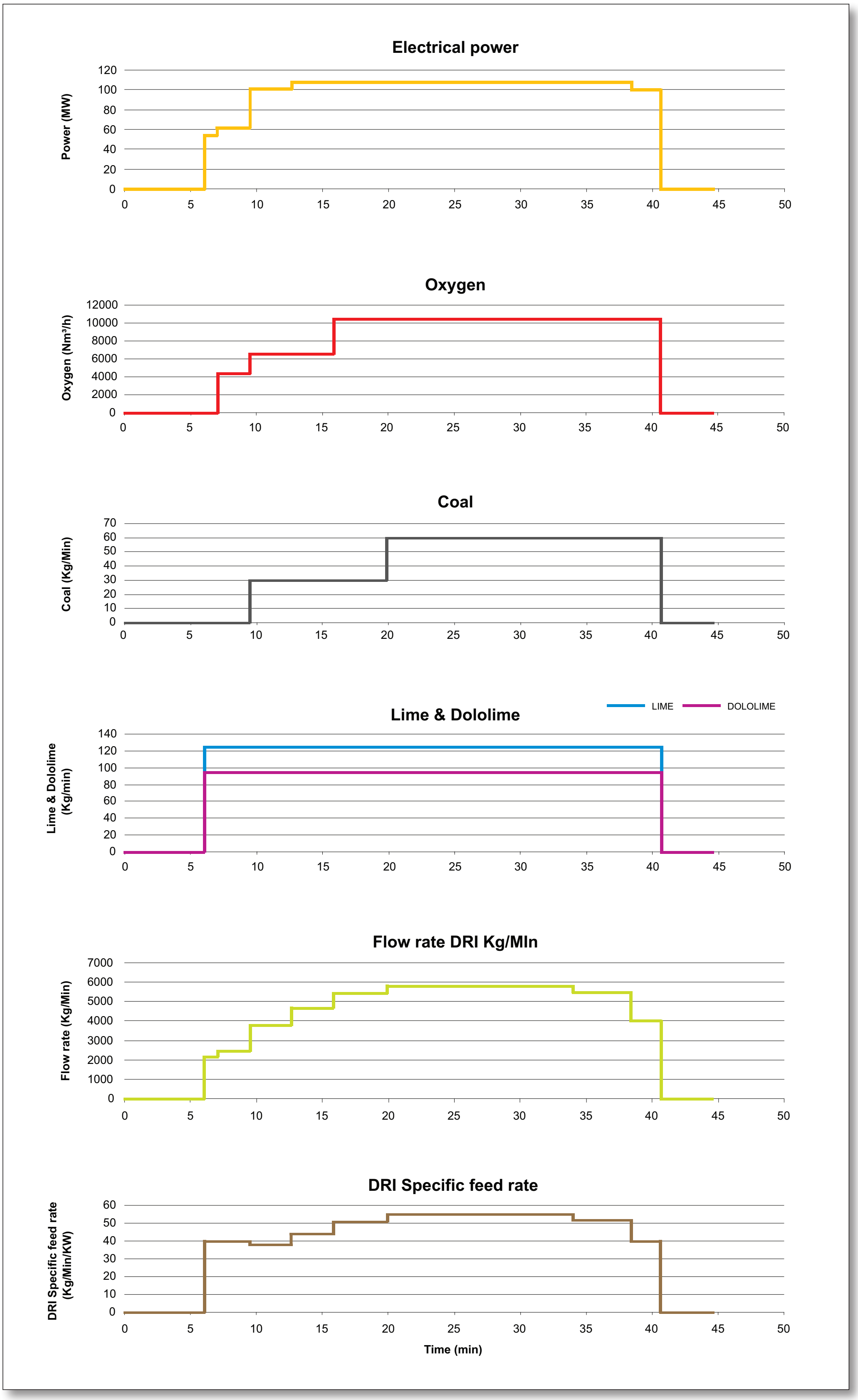

Fig 3 Melting profiles

Time	A Fe metalisation %	B Fe total %	C Metalisation %	C %	S %
08.00	87.8	91.8	95.6	2.07	0.011
10.00	86.3	91.6	94.2	2.15	0.009
12.00	86.9	91.6	94.9	1.94	0.008
14.00	88.6	93.1	95.2	2.12	0.009
16.00	86.9	91.6	94.9	2.20	0.007
18.00	87.2	91.7	95.2	2.16	0.008
20.00	86.6	91.2	95.0	1.81	0.009
22.00	86.8	91.4	94.9	2.21	0.010
01.00	87.3	92.2	94.7	2.13	0.008
03.00	87.3	92.8	94.1	2.17	0.010
05.00	88.0	92.9	94.7	2.06	0.010
Average	87.2	92.0	94.9	2.09	0.009

Table 4 **DRI analysis (note: A=B*C)**

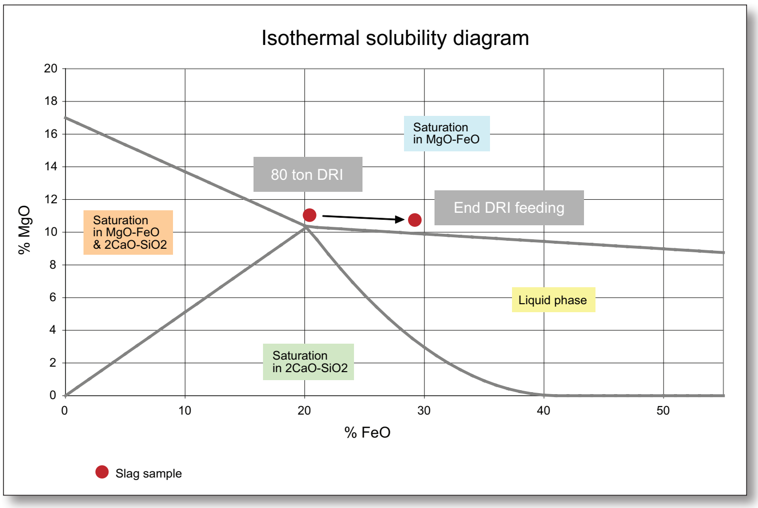

Fig 4 **Isothermal solubility diagram**

electrical energy equal to 141kWh/tls and a power-on reduction of 13.9mins.

The energy benefit comes mainly from:

- The enthalpy of the raw material corresponding to 105kWh/tls
- Additional 1.5Nm^3/tls oxygen used with hot DRI, corresponding to 4kWh/tls
- Improved metallisation of the hot DRI with respect to the cold DRI. The delta is equal to 1.7% corresponding to 23kWh/tls
- Reduced thermal losses due to decreased power-on time, corresponding to 9kWh/tls

Considering the DRI feed rate was kept at 5.8t/min (55kg/min/MW) during the main phase of the process, the oxygen injection system achieved correct decarburisation of the bath, corresponding to a specific rate of 320kg/m^2/hr.

Slag control Slag samples are taken at the end of the heat just before tapping. Typical slag composition is reported in *Table 7*.

Slag formers are continuously fed with the DRI to maintain slag basicity by compensating for the acid gangue of the pellets. To promote the initial foaming and enable the electrical power to ramp up quickly when the level of the bath is low, higher specific additions of slag formers are made in the first third of the heat, reaching values of 58kg/t DRI. During the main DRI addition this value decreases to 38kg/t DRI, increasing again to 55kg/t DRI in the final stage of the heat when bath and slag temperature are higher.

When compared with a scrap-based process particular attention must be paid to the MgO content of the slag as the refractory walls are potentially exposed to arc radiation immediately the power is switched on. An MgO-saturated slag will not only be less aggressive towards the refractory but also increase foaming. The target is a basicity IB_2 (CaO/SiO_2) is 2.1, or an IB_3 ($CaO/[SiO_2+Al_2O_3]$) of 1.7. The MgO saturation value is 10% according to *Figure 4*. The slag basicity is controlled throughout the process as shown in *Figure 4* where we can see how the slag composition changes between the 80t of DRI fed and the end of DRI feeding. Although Fe oxidation increases towards the end of the process, the MgO saturation value is maintained, allowing favourable slag foaming conditions.

In terms of refractory consumption this slag practice helped achieve the refractory guarantee figures. Regarding walls, bottom and roof delta, consumption was 2.48kg/tls for an overall refractory consumption of 4.8-4.9kg/tls. These data refer to a non-optimised hot DRI practice, so further consumption savings can be expected in the coming months.

PROCESS YIELD

One of the main targets of the project was to achieve a process yield of 86%, defined as the ratio between liquid steel and charged DRI. A value of 87.7% was attained. Particular attention was paid in the design of the furnace and of the process to avoid material losses in the FTP and through the slag door. On the basis of the data collected during the 10 heat performance test, the yield of good billet from charged DRI was 87.5% and for a 28-heat day production run, yield was 87.2%.

A deeper analysis of yield is as follows. Data on slag and FTP dust weights are collected on a regular basis. The average results for January 2010 were 145kg/tls of slag and18kg/tls of dust. Starting from the slag weight data it was possible to determine the iron lost in the slag according to the gangue content of the DRI, slag forming addition and refractory consumption. The results equate to 31kg of Fe/tls.

On this basis it was possible to determine the total losses of the charge as 140kg/tls and categorised as shown in *Figure 5*. Losses are detailed below:

- FTP dust; 18kg/tls confirmed from data collected on site, and indicating the right choice in terms of EAF roof design and DRI feeding point
- Decarburisation of the charge is 23kg/tls. The value comes directly from the difference in carbon content in the charge and the tapping carbon in the steel
- DRI gangue is 52kg/tls. According to DRI analysis the gangue content is about 4.5%
- Oxygen in the charge is 16kg/tls, calculated according to DRI metallisation of 94.85%
- Iron lost in slag is 31kg/tls. Slag losses through the slag door are minimised by process control.

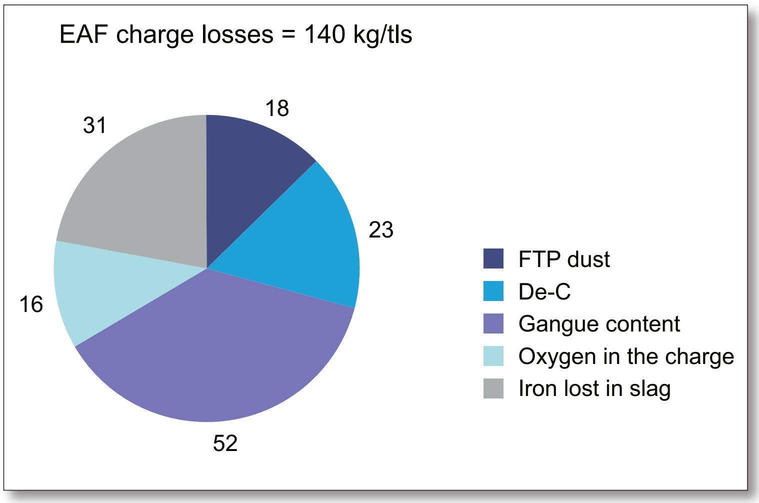

Fig 5 **EAF charge losses**

	A 90% hot DRI, 10% cold DRI	B 100% cold DRI
Tap-to-tap, min	45.5	58.5
Power-on time, min	35	48.9
Electrical energy, kWh/t	392	533
Oxygen, Nm^3/tls	34.8	33.3
Coal injected, kg/tls	9.7	17.3
Coal 5th hole, kg/tls	3.2	10.0
Average power, MW	102	98
Tapping temperature,°C	1,640	1,640
Steel liquid tapped, t	152	150

Table 5 **Consumption figures**

CaO	MgO	SiO_2	Al_2O_2	MnO	FeO
37.7	10.8	17.9	4.2	0.9	28.3

Table 6 **Typical slag composition, %**

This total loss of 140kg/tls equates to an EAF charge yield of 87.7%. It can also be expressed as a yield of 95.3%, the ratio between liquid steel and total iron in DRI which is 92%, ie, excluding the gangue content which is a direct consequence of iron ore quality. The results achieved so far represent one of the highest yields reached for 100% DRI-based processes.

FUTURE DEVELOPMENTS

A further improvement will be to increase DRI carbon content up to 2.5% with a proportional increase in oxygen total flow rate, and to operate with 100% hot DRI. DRI production will increase from 220 to 250t/hr. The plant handling system will soon be upgraded to cope with this. The expected results, based on a charge of 100% hot DRI at 600°C, will further reduce electrical energy consumption to 380kWh/tls and a power-on time of 34mins. This will increase productivity to 220tls/hr, with a tap-to-tap time of 41mins.

CONCLUSIONS

ESI's EAF process exceeded contractual figures, showing excellent thermal efficiency by exploiting the quality and enthalpy of the hot DRI charged. The plant is a good benchmark thanks to the excellent results in process time, electrical consumption and thermal efficiency. **MS**

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