Use of DRI in EAF's

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Part II: Feeding and Melting of Direct Reduced Iron

Introduction

Perhaps the most important consideration an operator gives when using direct reduced iron (DRI) or it's closely related cousin hot briquetted iron (HBI) is determining the percentage of DRI to use in the melting furnace. If the percentage of DRI is more than 35% of the total charge weight it should be continuously charged.

Some meltshops use DRI as a dilutant of the residual elements Cu, Ni, Sn, Mo and Cr so that the shop can produce critical steel grades with more restrictive chemical and physical specifications. The boil caused by continuously feeding DRI lowers the dissolved nitrogen and hydrogen levels in liquid steel.

Other meltshops use DRI because of economics. In many places steel scrap is unavailable or of such low quality and density so that the continuous feeding of DRI eliminates multiple scrap charges.

Factors such as feeding and power input rates flux consumption and tap to tap times are greatly influenced by DRI chemical composition. The operator must take into account the final chemical specification of a grade of steel to define the DRI feeding rate and melting practice to produce the most economical heat of steel.

Continuous Feeding of DRI to an EAF

Continuous feeding of DRI or HBI is accomplished by conveying the materials from a storage silo to the top of the melt shop. From there it is fed by a series of bins and belts through a weighing system, down a chute or pipe and into the furnace proper through a hole in the roof. Many schemes have been tried for locating the feed hole but generally the hole is located on the half of the roof between the electrode(s) and the rear wall.

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When using DRI an EAF operator should maintain a liquid heel ranging from 15 to 30 % of the tap weight. This means that the EAF has to run around the clock to prevent freezing of the liquid heel. EAF’s using 90 to 100 % DRI or HBI will need to start continuous feeding very quickly after initial arcing.[1]

DRI feed rates range from 5 kg/min-MW up to 35 kg/min-MW. The DRI feed rate is increased in a series of steps.[2] The maximum feed rate is highly dependent on the quality of the material with respect to carbon, gangue and metallization.

The operator wants to maintain a feed rate that stabilizes the liquid bath temperature around 1570 C. This temperature when combined with the proper composition of slag, oxygen and carbon produces the best slag foaming performance in the furnace.

Calculation of the proper DRI or HBI feed rate is done in terms of Specific Energy (kWh/charge ton[*]). Defining the Specific Energy for each part of a heat is an iterative process depending on the consistency of DRI composition, slag additions, slag foaming and the furnace power parameters.

Perhaps the best way to examine continuous feeding is through the use of an example:

Furnace Operating Parameters

Hot Heel wt.	40 ton
Initial Charge wt.	45 ton
Total Charge wt.	170 ton
EAF tap wt.	150 ton
Maximum Power	91 MW
HBI Feed Rates	30 to 165 ton/hr

First the initial charge is melted. Feeding of HBI is started at 200 kWh/ton as shown in Figure 1. The feeding and power input rates are quickly increased as the specific energy increases. Near the end of the melting time the feed rate is decreased to produce an increase in the bath temperature. Figures 1 define the melting practice with respect to feeding rates, and energy consumption. Figure 2 defines the power input at various stages during the melt.

[*] Note: All tons are metric

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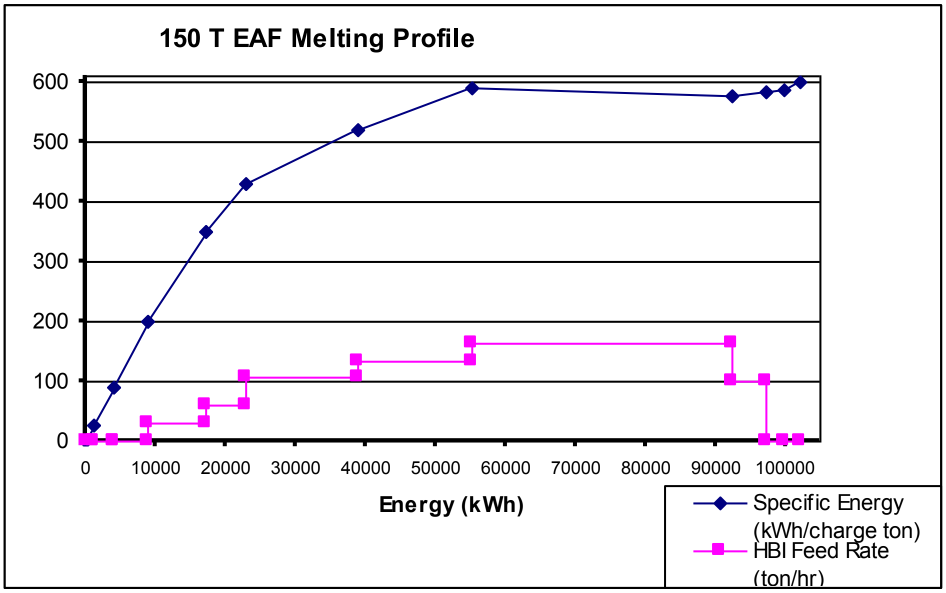

Figure 1. Melting Practice with Respect to Energy Input and HBI Feed Rate.

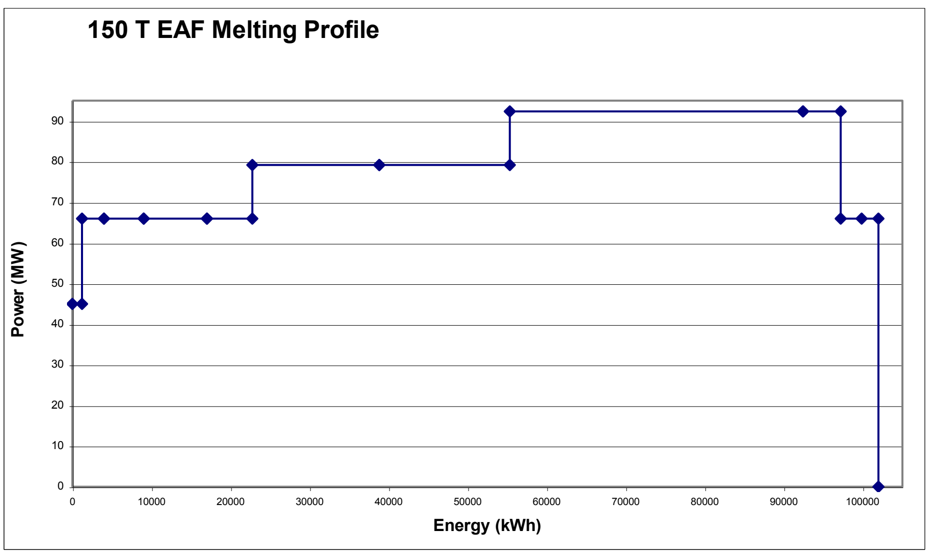

Figure 2. Melting Practice with respect to Power Input.

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Power input is very dependent on good slag foaming. Since continuously fed DRI is charged into a flat bath, slag foaming is necessary to insulate the arc, protect the furnace refractory and reduce the density of the slag so the DRI can penetrate the liquid steel melt.

Power input practice is reversed as compared to a scrap melting EAF. The arc lengths and corresponding power inputs are kept low until the feed rate is raised as the heat progresses and slag height increases due to foaming. Depending on the EAF power source, AC or DC, an operator must experiment with the arc lengths to minimize both heat times and energy consumption.

Although situations are different at each meltshop, the following general equation can be used to determine the time for each step for continuously feeding DRI:

$$SE_i \times (\Sigma CW_i + FR_i \times t_i) = MW_i \times 1000 \times t_i/60 + \Sigma kWh_i,$$

Where: SE_i = Desired Specific Energy (kWh/ton) at the end of each step

CW_i = Charge Weight at the start of each step (ton)

FR_i = Feed Rate (ton/min)

t_i = time (min)

MW_i = Power (MW) Input in each step

kWh_i = Energy at the start of each step (kWh).

The equation is solved for time at each step. Based on the equation, experimentation and experience, an operator can determine the desired feed and power input rates at certain times during the melt.

If the material is fed too fast, an operator may observe a large solid clump of DRI or HBI mixed with lime floating around the furnace. This is known as a "Ferroberg". Due to the lower apparent density of DRI, 3.4 and HBI, 5.5 as compared to liquid steel, 6.9 gm/cm^3, very little mass of the Ferroberg is immersed in the liquid steel and much is exposed above the top of the slag.

Melting of the Ferroberg is mostly done by thermal radiation, which is an inherently slower melting process as compared to conduction and convection heat transfer

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processes. The operator needs to cut back the feed rate immediately upon observation of a Ferroberg.

Consistent DRI or HBI chemistry is vital to controlling the feeding process. A Level II system controlling the EAF operations is very useful when continuously feeding DRI.   If the EAF operator has a captive DRI module producing material with uniform chemistry, the Level II model can be optimized to produce consistent tap to tap times, tap temperatures and energy consumption levels.

Artificial intelligence (AI) can be built into the Level II system to maintain and adjust power input and DRI feed rates for cold starts after downday, production delays and variable scrap mixtures.

If the EAF operator is buying DRI or HBI on the open market from different sources, the chemistry may be inconsistent from batch to batch. If the FeO level increases or carbon content decreases then the feed rate must be slowed. Therefore the operator must set up the Level II model in a conservative rather than optimal mode. This results in lower feed rates, longer tap to tap times and higher energy consumption levels.

Bulk Charging of DRI

Many existing shops lack the capability for continuous charging of DRI. In these cases it is necessary to charge the DRI with the scrap bucket. DRI or HBI material should be limited to no more than 35 % of the total iron bearing material charge weight. At higher levels, DRI or HBI tend to stick on the furnace walls.

In cases where low density scrap (0.30 to 0.65 t/m^3) is in use, it would be preferable to put the bulk charge of DRI or HBI in the first furnace charge. This would fill the furnace shell with higher bulk density material earlier in the heat and prevent the need for a third bucket depending on the EAF shell volume.

References:

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1. R.D. Morales, et. al.,"The Slag Foaming Practice in EAF and Its Influence on the Steelmaking Shop Productivity," ISIJ International, Vol. 35 (1995) No. 9, pg. 1057, Fig 5.
2. Taylor and Custer, Electric Furnace Steelmaking, Iron and Steel Society, 1985, pg. 117

Biographical Information

Gregory L. Dressel, P.Engr. is a metallurgist working in private practice. Mr. Dressel provides consulting services to suppliers and steelmakers in starting up new equipment or improving existing operations. He consults on raw material selection, operator training, melting practices, ladle refining, continuous casting and quality engineering. He can be contacted by E-Mail: gregdressel@dresseltech.com or phone and fax at +1 843 237-8337.