Potentialities of alternative Charge materials for the electric arc furnace

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Abstract

Traditionally, scrap has been the raw material feed to the electric arc furnace, but increasingly DRI, pre-reduced pellets, HBI, pig iron, hot metal and iron carbide are being focussed as potential alternative charge materials for the electric arc furnace. The partial substitution of scrap by these charge materials improves the quality of steel, decreases energy consumption and increases productivity.

Introduction

The electric furnace route is becoming popular day by day. During the last one and haf decade about 30% of world's total crude steel has been produced in electric arc furnaces and it is expected that by the end of 20th century EAF steelmaking will account for about 40% of the total steelmaking [1-5]. Efforts are being made in U.S.A to produce steel on continuous basis in Electric Arc Furnace [6-8]. Further the objectives of EAF steelmaking are to reduce refractory wear and improve melting efficiency. The major technological developments in electric arc furnace are transformer up rating, scrap preheating, use of oxyfuel burners, new electrode technology, water cooled panels, control of emissions, treatment of dust, eccentric bottom tapping, powder injection, foamy slag practice, slag free tapping, inert gas bubbling, computerized charging, process automation and substituting part of scrap mix by DRI or HBI. Fast technological developments between 1980 and 1990 led to the reduction in power consumption by 21%, decrease in electrode consumption by 60%, increase in the productivity by 45% and shortening of tap to tap time from 90 to 60 minutes. The energy saving measures included the improvements in operating practice, investment in energy saving equipments and modernisation of process and equipments. The direct current electric arc furnaces [11-13] will be available in near future with improved melting efficiency and reduced refractory wear.

In view of the deteriorating quality of scrap, fluctuating prices and non-availability of scrap, the DRI and HBI with its consistency of composition, lower content of tramp elements and particularly low phosphorus and sulphur have drawn the attention of steel producers in small scale and medium scale sectors to make use of pre-reduced materials. Scrap can be substituted partially by DRI, HBI or iron carbide.

This paper discusses the potentialities of partial substitution of scrap by alternative charge materials and their influences on the quality of steel, cost, energy and productivity.

Alternative charge materials for electric arc furnace

Traditionally scrap has been the usual and, partically, the only iron bearing source to feed the electric arc furnace. However, direct reduced iron (DRI), Pre-reduced pellets, hot briquetted iron (HBI), pig iron and hot metal are being focussed as possible alternative charge materials for the electric arc furnace (EAF). The type of the charge and charging practices in EAF are discussed in Table-I. DRI or HBI is produced by various direct reduction processes. A typical HBI composition has been illustrated in Table-II, which indicates close similarity in chemistry with typical DRI. Being heavy and non-porous structure (bulk density of 2.4 - 2.8 t/m^3) HBI has higher thermal and electrical conductivity. The selected characteristics of these metallized products are given in Table-III. They can be charged either in cold form at ambient tempeature or can be preheated, usually in the range of 500° to 700°C, possibly to 900°C before charging into the furnace. Pig iron can be used in solid form (pigs, granulated iron etc.) or as liquid "hot metal". Hot metal at around 1300-1400°C can be charged to EAF. Iron carbide is emerging another alternative charge material for the electric arc furnace. It contains no sulphur and is low in residuals. It is finely divided and not pyrophoric, as a result it dissolves and melts rapidly. It can be injected into electric arc furnace easily, and iron unit recovery is excellent. Since it has excess carbon relative to any remaining iron oxide, it results in complete reduction of the oxide.

Metallurgical evaluation of alternative charge materials in the electric arc furnace

The briquetted forms of DRI, known as hot briquetted iron (HBI) is originally compacted to avoid the spontaneous combustion and reoxidation problems (pyrophoricity) which are generally associated with DRI. The metallurgical evaluation of HBI has been done[15] in terms of its degree of metallisation and gangue content as well as the proportion added in the charge, vis-a-vis EAF parameters like energy consumption, productivity, electrode consumption, refractory lining wear rate, lime consumption (slag volume) metallic yield, long arc and foamy slag operation. It is observed that HBI with 93 to 94% metallisation and least acid gangue ($SiO_2 < 1\%$), low P and S (<0.03%) content, if continuously charged [16-18], can substitute scrap up to 50 to 60% depending upon the size of the furnaces and relative pricing of scrap and HBI. Figure-1 shows the dilution effect of addition of HBI upon the bath residual metal level with medium quality scrap. The content of copper , which is frequently associated with hot rolling difficulties and rolling mill yield losses, is decreased significantly. On account of low impurity levels, it is possible to produce a wide range of quality flat-products, including the extra deep drawing quality grades. It may be difficult to produce high quality mini mill product through utilizing scrap alone unless quality scrap availability is assured. The addition of HBI to scrap can also result in a significant decrease in the input to the melting furnace of refinable impurities such as sulphur and phosphorus provided the HBI is produced from quality prime ore. Figure-2 shows the high quality steel products with HBI.

Because of higher slag volume, the higher proportion of HBI in the charge mix leads to higher energy consumption. However, by putting stringency on HBI quality by way of higher metallisation (lower FeO_x), lower acidic gangue content and lower amounts of refinable impurities (like S, P etc.), the energy escalation in EAF can be curbed. Operating practices in Mexico and Germany have shown that (i) with 50% HBI in the charge mix, as carbon content was increased from 1 to 20%, the energy dropped from 640 Kwh/t to 615 Kwh/t and (ii) a 3% rise in metallisation of HBI (e.g. from 92 to 95%) generally lowered energy consumption of upto about 20 Kwh/t. In the Indian context, since the quality of DRI/HBI has not been of consistently desired grade, it is observed that there was an increased power consumption of over 60 Kwh/t while using a 70:30 ratio of scrap to HBI. Therefore, the proportion and quality of HBI has to be optimized. It has been found that with a desired quality of HBI, the rise in the energy consumption can be kept under control when charging system is changed from batch to continuous one (Fig-3).

Iron carbide is also an ideal material for steelmaking. It can be used as sole feed for a conceptual, new, continuous steelmaking process[19]. In this process iron carbide is fed into a reactor. The carbon is removed from the bath, using oxygen, burned to CO_2 and liquid steel is tapped continuously from the discharge end, while countercurrently flowing slag is tapped from the opposite end. The heat and material balances for such a process indicate that the process is feasible. Likewise, the iron carbide fines can be successfully injected into the EAF for producing quality steel. The storage and transportation of iron carbide is easier in comparison to other charge materials. It can be briquetted also using a binder, although binder often introduces impurities, such as hydrogen and sulphur. The strength of such briquettes totally depends on the type binder. Since iron carbide has high melting point and in practice it dissolves in molten steel, it is preferable to introduce it into a EAF as a finely divided material.

Potentialities of alternative charge materials in EAF

(i) Effect of charge materials on the quality of steel

The electric arc furnace is a steelmaking reactor and with its impressive new achievements, it is tempting to go further with different charge materials. The objective of making use of alternative charge materials[14] is to improve steel quality, decreasing energy costs and increasing productivity.

Pig iron, DRI, pre-reduced pellets, HBI and iron carbide have been recently used in several plants and they offered the advantage of producing steel with low residuals (Cu, Ni, Mo etc.), low metalloids (P,S) and low amount of gases (O,N).

The important incentive to use such alternative charge materials is to produce quality steel and to move "upmarket" as in the case of flat products.

(ii) Effect of charge materials on cost and energy

The basic energy needs and supplied[14] in electric arc furnace are shown in Table IV and V. The use of liquid hot metal greatly decreases the energy needs because the carbon content in the melt from hot metal or iron carbide will provide heat on oxidation. The use of DRI or HBI will need more energy because of the increase in the residual oxygen.

The alternative charge materials can have different merits depending on the price of scrap in the various regions of the world. If scrap is scare and costly to import, DRI or eventually pig iron can be quite attractive economically.

(iii) Effect of charge materials on productivity

The use of preheated charge or liquid hot metal decrases the operating time and increases the productivity of EAF, but the use of DRI or HBI would increae energy consumption and operating time. However, the use of continuous charging of iron carbide with less residual oxygen and more carbon will decrease energy needs as well as operating time. Thus, the alternative charge materials can offer an interesting opportunity for new technology such as continuous charging/injection techniques.

Further anticipations of altgernative charge materials

The future of EAF steelmaking will depend on (i) the cost of scrap and (ii) the partial substitution of scrap by DRI, pre-reduced pellets, HBI, iron carbide, pig iron and hot metal. The various interesting combinations of scrap with alternative charge materials in the charge mix of EAF can be as follows :

(i) Scrap + pig iron
(ii) Scrap + pig iron + DRI/HBI/Pre-reduced pellets
(iii) Scrap + High carbon DRI/HBI, and
(iv) Scrap + iron carbide

In developing areas, EAF can be integrated with primary metal producing unit such as (i) Integration of DRI unit with EAF, (ii) Integration of hot metal producing unit with EAF namely the combination of mini blast furnace or smelting reduction unit (such as COREX, producing hot metal) with EAF.

Conclusions

- o DRI/HBI/Pre-reduced pellets as a feed constituent to supplement scrap dilutes residuals enhance the quality of steel
- o The proportion and quality of DRI/HBI/Pre-reduced pellets has to be optimized in order to derive maximum benefit out of this charge constituent.
- o Iron carbide can be successfully injected into the EAF to partially substitute scrap for producing quality steel
- o With the use of alternative charge material, EAF can improve its technology and compete with conventional integrated iron and steel plant both from the point of view of quality and cost of steel.

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Table-I :Type of the charge and charging practices in EAF

Scrap	DRI/HBI/Pre-reduced pellets	Pig iron/Hot metal	Charge temperature
Conventional practice	Conventional practice often with continuous charging	Pig iron usually used in small addition	Cold
With scrap pre-heating	New trend such as HYTEMP		Hot 500-750°C
		Hot metal practice	Liquid

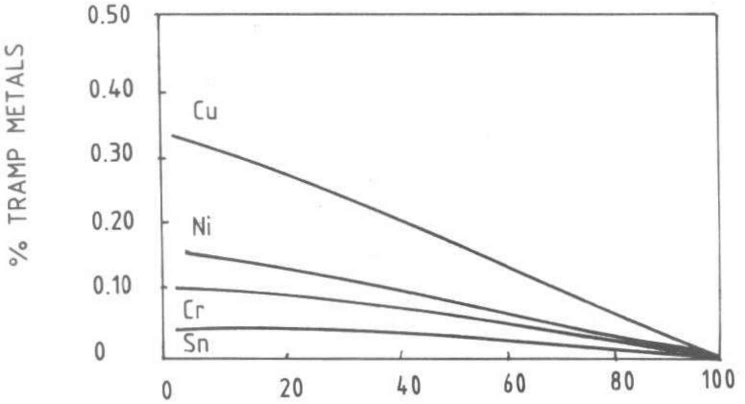

Fig.1 : Effect of HBI on melt-in tramp element content

Table-II : Typical characteristics of HBI and DRI

	HBI/DRI	(in general)
Total Fe, (%)	94.1	90-94
Metallic Fe, (%)	88.0	83-89
Carbon (%)	0.20	1.0 - 2.3
Sulphur(%)	0.015	0.001 - 0.03
Phosphorus (%)	0.085	0.005 - 0.09
Gangue (%)	3.0 - 5.4	2.8 - 6.0
Cu, Ni, Cr, Mo, Sn (%)	Traces	Traces
Physical size (mm)	30 x 50 x 110	4 - 20
Apparent density (g/cm^3)	5.0 - 5.5	3.5
Bulk density (t/m3)	2.4 - 2.8	1.6 - 1.9

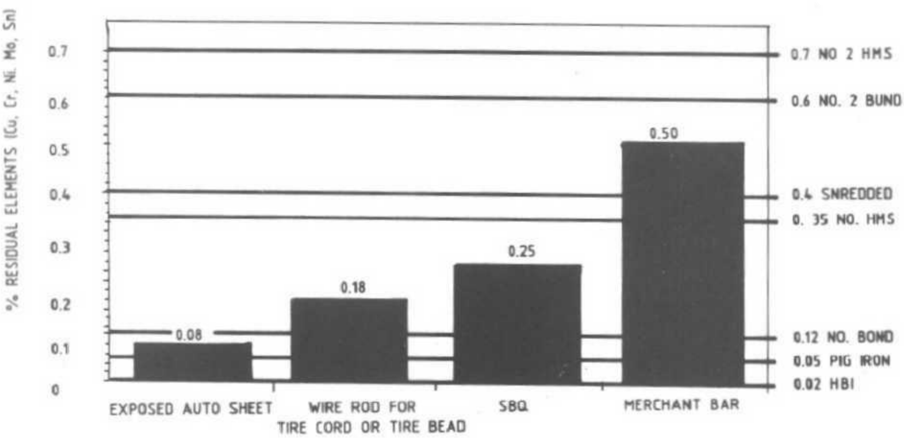

FIG. 2 HIGH QUALITY STEEL PRODUCTS WITH HBI.

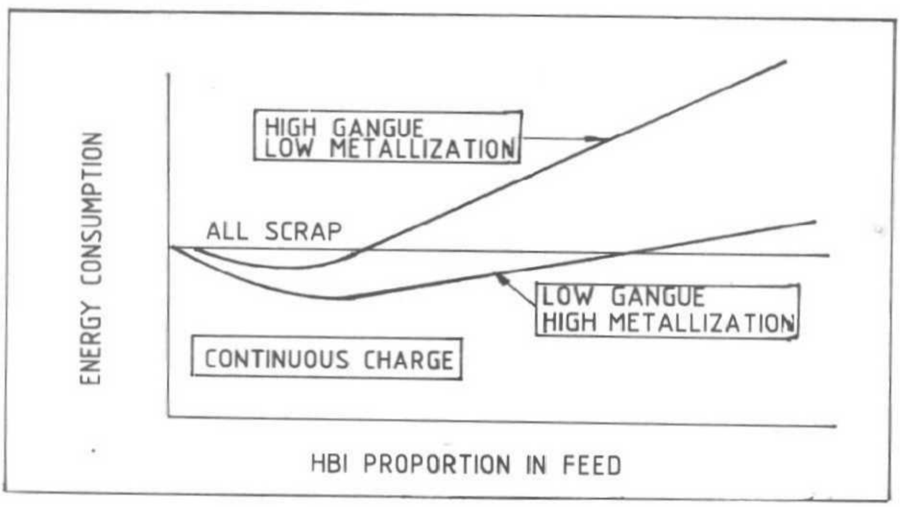

FIG.3 EFFECT OF CONTINUOS CHARGING OF HBI ON ENERGY CONSUMPTION.

Table-III : Typical characteristics of metallized products

Characteristic	Metallized Pellets	Cold-formed briquettes	Hot formed briquettes
Iron content (%)	92	87	92
Porosity (%)	50 - 60	25 - 30	15 - 20
Density (g/cm^3)	3.3	4.0	5.8
Loose mass (t/m^3)	2.0	2.8	3.2

Table-IV : Simplified energy needs in the EAF

To heat and melt 1 kg Fe at 1600°C	1.35 MJ
To dissociate FeO to Fe and O per kg O	16.8 MJ
To heat and melt 1 kg slag at 1600°C	1.6 MJ

Table-V : Simplified possible energy supply in the EAF

1Kwh	=	3.6 MJ
1 kg C burnt to CO	=	9.2 MJ
1 kg C burnt to CO_2	=	32.8 MJ