Techno-economic aspects of alternative metallic charges in EAF steelmaking

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Electrical arc furnace steelmaking originated with the work of Sir Williams Siemens who in 1878 constructed, operated and patented furnaces operating on both the direct arc and indirect arc principles. The development of the electric melting furnace, however, had to await the expansion of the electric power industry and improvement in carbon electrodes. The use of electric arc furnace for steel making was perhaps first adopted in the later part of the 19th and beginning of the 20th century. Major commercial applications of the process began with the production of low alloy steels and subsequently high alloy and special steels. With the developments that have taken place over the years in EAF technology, ladle metallurgical and continuous casting, EAF plants are now entering into new areas, hitherto considered as exclusive domain of conventional large integrated steelmakers. Today Electric Arc Furnace (EAF) steelmaking accounts for over 30 per cent of the crude steel production in developed countries like USA, Japan and nearly 100 percent in the oil/gas rich countries of the Gulf region and the Middle East.

Technical Development Affecting EAF Productivity

In the past 3 decades or so, various technical developments have progressively improved the efficiency and productivity of the electric arc furnaces. The technical developments include the use of ladle furnace and secondary refining facilities in combination with EAF to improve the overall performance. It should be noted that no single factor was responsible for this dramatic improvement in productivity. It was the result of a combination of technical developments and improved operational practices.

Technical development trends in EAF steelmaking over the past 3 decades are summarised in Fig-1. The characteristic features of the technical developments can be summarised as followed :

- Power system has been designed to more than 900 KVA per ton of liquid steel
- Oxygen consumption has become a compulsory feature to improve productivity and save electrical energy. The oxygen consumption can be as high as 40 cu.m/TLS of liquid steel with liquid iron charge, this specific consumption of oxygen may increase further.
- Water-cooled walls and roofs
- High power operation
- Use of eccentric/concentric bottom tapping

- Preheating of scrap
- Automated/semi automated oxygen and carbon injection manipulating devices, pneumatics bath stirring etc.

The tap-to-tap time has improved more than three-fold. Today, it is around 55-60 minutes compared to 180-220 minutes in the mid 60s. Specific power consumption today is around 350-400 kWh per ton compared to 630 kWh in the mid 60s. The specific consumption of electrode per ton of liquid steel has also improved to a level of around 2 kg at present from that of 6.5 kg earlier.

Metallic Charge for EAF Steelmaking

Steel making through EAF route involves following major process steps :

- Charging EAF with the major iron bearing inputs
- Melting of iron bearing units
- Formation of a good working slag to remove undesirable elements
- Oxidation to remove non-metallics and undesirable metal constituents
- Addition for composition adjustment
- Casting of the finished steel directly from the furnace or through ladle furnace at a correct temperature

Since the inception of EAF as commercial steelmaking unit, steel scrap has been the principal metallic charge. With the growth in EAF steel making, wide -spread adoption of continuous casting and increasing scrap utilisation in BOF vessels, the demand for scrap for as a melting stock has been steadily increasing. Further steel users are demanding higher quality steel, and hence, good quality scrap low in tramp elements is becoming increasingly important in the steel making process. Consequently, good quality scrap is getting harder to come by and the price are constantly fluctuating.

According to a recent survey, the gap in the world metallics scenario is expected to be in the region of 40-50 million tons over the next decade, as shown below and illustrated in Fig-2. This gap will have to be bridged by substitute sources of iron such as DRI/HBI or iron carbide.

	1998 mill.tons	2003 mill.tons
Crude steel production	774	800
Metallics requirement	907	949
Anticipated availability of hot metal & scrap	869	899
Gap to be bridged	38	50

Likely Future Scrap Situation

Traditionally, EAF plants have been dependent on purchased scrap. During the 70s and early 80s, the question being debated at international fora was : Is enough scrap available ?" Today, that question has been redfined as : Is enough scrap of *suitable quality available, at prices that will allow EAF units to remain competitive ?*

The scrap market is cyclical, it is primarily demand-driven and also supply-constrained. The past trend of international scrap prices shows definite peaks and troughts occurring at intervals of 3-5 years. After hovering at levels of US $ 80 to US 100 per ton f.o.b. during 1991 and 1992, the price of scrap in the international market started to rise in 1993. Currently, the f.o.b price of Heavy Melting grade scrap is about US $ 130 per ton. It is excepted that over the next few years, the average price of scrap will be in the region of US $ 150 per ton f.o.b.

In India, the price of imported scrap delivered at the port of entry was around Rs 5,000 per ton during 1993. At present it is about Rs 5,500 per ton.

Alternative Charge Materials

In view of the tight availability of good quality scrap and the rising trend in prices, EAF steelmakers are exploring all available options for replacing scrap with other materials. In this context, DRI/HBI has become increasingly popular with EAF steelmakers the world over. Recently, pig iron has also garnered some support in view of its high iron content and low residual levels. For instance, at NUCOR's Crawfordsville plant, much of the bundle charge has been replaced with pig iron. As a matter of fact, NUCOR has also set up an Iron Carbide plant in Trinidad as a captive source of virgin low residual metallic charge.

In India and in other countries where electric power cost is high, the use of hot metal as partial replacement for scrap is gaining favour. The primary objective is to reduce power consumption by making use of the sensible heat in the hot metal. However, this option necessitates the location of the hot metal source in close proximity to the EAF.

Techno-economic Aspects of Alternative Metallic Charges

As mentioned earlier, EAF operation today can be based on various alternative charge materials like scrap, pig iron/hot metal, HBI/DRI, and iron carbide. In the Indian context, th use of scrap HBI/DRI and hot metal seems to be relevant and has been considered in this presentation.

The alternative charge-mixes which have been selected for comparative evaluation are as follows :

Alt.1	:	100% scrap
Alt.2	:	50% scrap + 50% coal-based DRI
Alt.3	:	50% hot metal + 50% coal-based DRI
Alt.4	:	50% hot metal + 50% gas-based DRI/HBI

On the basis of a computer model, the production costs of billets for the above charge-mixes have been worked out. For this purposes, the following basic assumption have been made :

- 30-ton EAF with 18 MVA transformer
- No ladle furnace
- Continuous DRI/HBI charging through furnace roof
- Billets of mild steel grade

The computer model adopted for obtaining mass and energy balance is also capable of computing the total specific energy requirement, tap-to-tap time, power regime for continuous DRI/HBI charging, blowing time for hot metal charge and a number of other operating variables.

The results of the model analysis for the four typical charge mixes are summarised below :

	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Heat time(mins)	90-95	100-105	100-105	95-100
Billets, tons/yr	150,000	130,000	130,000	135,000
Consumptions per ton billet :				
Scrap, kg	1,080	575	580	575
DRI/HBI, kg	-	575	580	575
Hot metal, kg	-	-	580	575
Flux, kg	35	90	135	100
Electric power,kWh	560	700	400	340
Oxygen, N Cu.m	20	25	40	40
Production cost index per ton billet(excl. capital related charged)	100	102	91	91

The unit prices of the major imputs considered for estimating the cost of billets are as shown below :

Input	Unit	Unit price(Rs)
Streel scrap	ton	6,300
Coal-based DRI	ton	4,800
Gas-based DRI/HBI	ton	5,200
Hot metal	ton	6,000
Eectric power	kWh	2.20
Oxygen	N cu.m.	3.70

The prices of steel scrap and electric power are the two major factors that effect the economics of EAF operation. Changes in the scrap price have a trigger effect on the prices of DRI/HBI as well. The effects of increases in the prices of these inputs on the production cost index of billets have been examined and are graphically illustrated in Figs.3 and 4. It emerges that, for the specific conditions and prices considered in this presentation, with scrap prices in excess of Rs 7,000 per ton, operation with a charge-mix of about 50 percent scrap and 50 percent DRI would be comparable with 100 percent scrap operation, On the other hand, with increase in the unit price of electric power, operations with 50 percent DRI and 50% scrap charge becomes less and less competitive when compared to 100 percent scrap operation. In all cases, operation with a charge-mix of 50 percent hot metal and 50 percent DRI/ HBI appears to be more attractive.

Conclusion

The Indian EAF steel industry is going through a phase of rationalisation and cost reduction. The existing plants are trying to find ways to increase their production capabilities, reduce operating costs and improve operations. Confronted with increasing power costs and rising scrap prices, the EAF industry in India is trying to evolve strategies that would keep the industry competitive in the rapidly changing steel scenario. Amongst the various option available are the use of DRI/HBI with predictable composition and very low levels of tramp elements, ideal for the production of quality steels, and the use of hot metal in the EAF in order to reduce the cost of power.

With the liberalisation of the Indian economy and the removal of subsidies, the EAF industry will have to formulate an appropriate strategy for its survival and growth. This will call for adoption of new and innovative ideas.

References

[1] The electric Arc Furnace - 1990, IISI, Committee on Technology, Brussels 1990.

[2] Srap: Will the Essential Input Limit Mini Mill Growth ? by the David J. Joseph Company, Cincinnati, Ohio, The Fifth Metal Bulletin Mini-Mill Conference, Dallas, Texas, March 17, 1988.

[3] Steel 2003 : A Road Map to the 21str Century by D.Barnett & J.T. Kopfle, ISS 53rd Ironmaking Conference, Chicago, March, 1994.

[4] Wanted : Low-residual Scrap by Ted Kuster, New Steel, AZpril, 1994.

[5] Minimills and integrated steel Plants by Prof. Williams T. Hogan, Steel Technology International 1994/95.

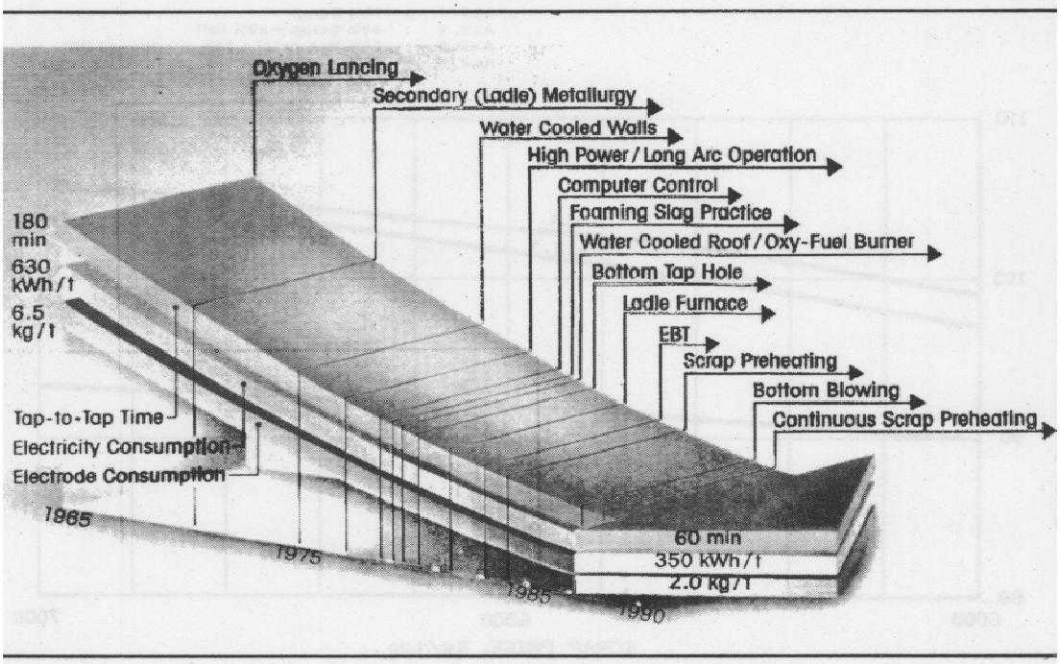

Fig.1 : Development trends in EAF steelmaking

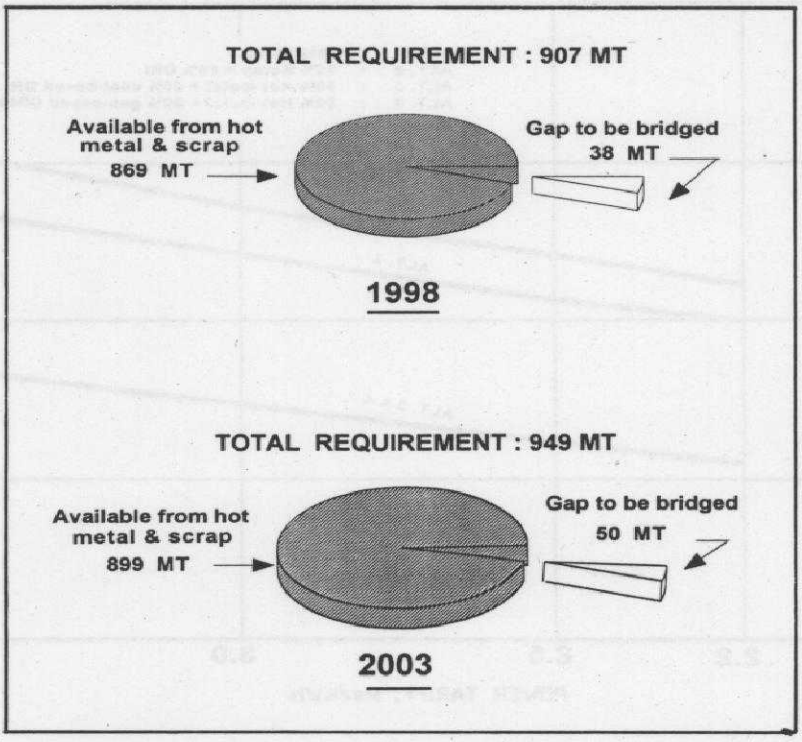

Fig.2 : Future world metallics situation

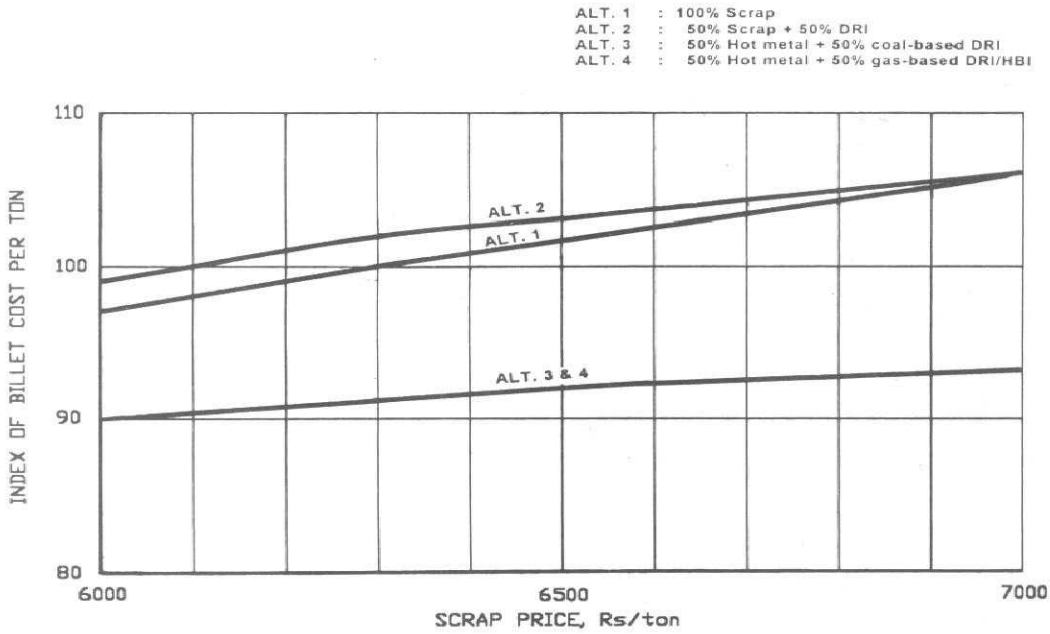

Fig.3 : Billet cost Vs scrap price

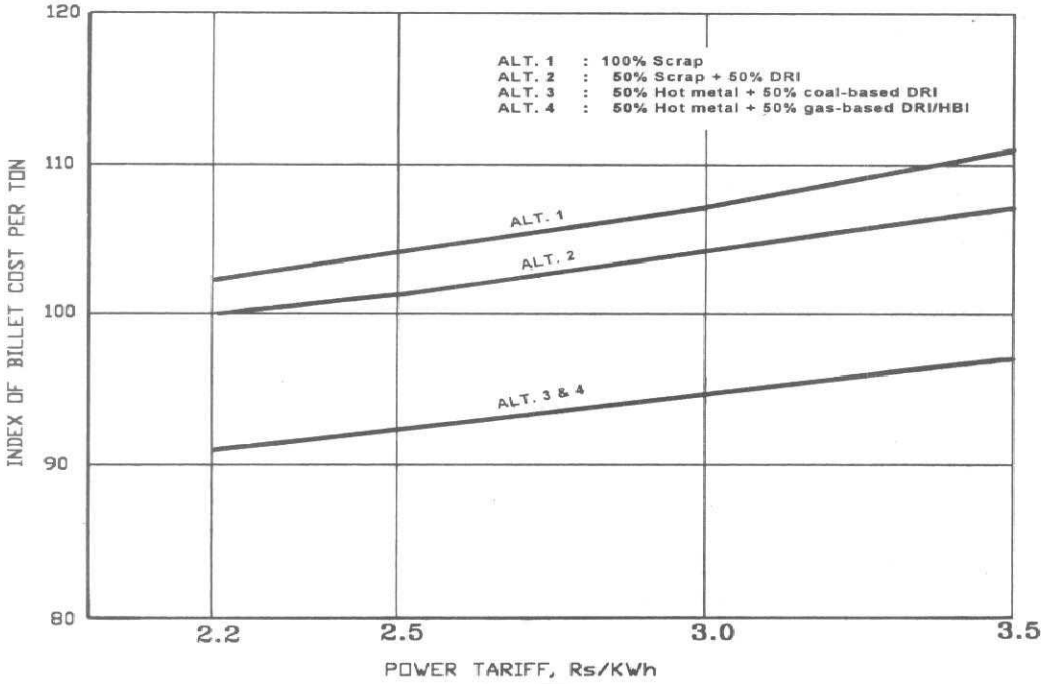

Fig.4 : Billet cost Vs scrap price