Technologies for cost reduction in EAFs

- By B.V.R.Raja, N.Pal, P.L.Talwar, N.P.Jayaswal
Alloy Steels Plant,
Steel Authority of India Ltd.,

Introduction

Electric Arc Furnace (EAF) steel making accounts for 33.10% of the world steel capacity and is considered to be the only route for making high alloy steels. Technological developments have been continuously taking place in EAF process for the past 40 years to improve upon capacity, productivity, efficiency and quality of the steels with huge emphasis on cost reduction. With advantages of lower investment costs coupled with better flexibility towards the input raw materials, energy inputs and steel grade mix, the world steel production through this route is projected to touch the magic figure of 50% by 2010.

Technological developments

Alternate scrap use

The major contributor for high production cost in EAF has been the raw materials wherein, metallic charge with 100% cold scrap accounts for 87% of the total cost of raw materials. Steel scrap has been the main source of metallic feed from EAF steel making. The consumption is to the tune of 900 Kg/T of liquid steel from a total charge of 1080 Kg/T of liquid steel if the metallic charge is mostly scrap. The physical and chemical characteristics of the scrap have a direct influence on the performance of EAF melt shop and its operating cost. Hence, the scrap price is crucial to the economies of electric steel making.

The advent of continuous casting has reduced the internal scrap arising which is of high quality from a level of 20% to 10% and further decreasing. The only growth in availability of scrap is from consumer durables and automobile industries which is of variable quality. There has been a growing trend in scrap preparation facilities throughout the world to upgrade the quality and recover notable non-ferrous metals through recycling. All this lead towards use of high quality scrap with the upgraded quality scrap from fragmentizing units as metallic feed in EAF for cutting the cost.

Scrap preheating systems

It is a well known fact that 20% of the energy generated in EAF leaves in the form of offtake gases. Preheating systems have evolved in various plants that use the waste gases to preheat the scrap about 250°C - 350°C and charged in the furnace to result in energy savings of 40 Kwh/ tonne. Fuchs' Shaft Preheater helps to integrate scrap preheating with the EAF wherein the first bucket of scrap is charged into the furnace with the roof open and rest through the shaft. Scrap preheating is done in the shaft by the offtake gases and there are about four oxy-fuel burners of 3 MW each installed in the side wall of the shell.

Consteel process is a method which involves sized scrap conveyed inside a tunnel like shell, hot furnace gases and gases from natural gas burners in the tunnel preheat the scrap and fed continuously to EAF. Davy-Clecim twill shell electric arc furnace in which scrap is preheated to 800°C-1000°C in one vessel by burners, while the other vessel is dedicated to electric melting. These processes were reported to reduce the power consumption by 200 Kwh/tonne of liquid.

Emerging low cost metallic feeds

The majority of scrap is consumed by Basic Oxygen Furnace units resulting in shortage of scrap for electric furnace steel makers. The rocket high prices of imported scrap is a cause of worry for EAF steel units. This led the steel makers through electric arc furnace route to look for viable options for substituting scrap by alternate low cost metallic feeds. Considering the scrap shortage, EAF steel melting shops are considering usage of metallic feeds like Sponge Iron and Hot Metal for reducing the production cost.

Sponge iron (DRI/HBI)

The evolution of sponge iron as metallic feed in EAF has been mainly due to its cost advantage over scrap. It is a high quality metallic product produced from iron ore/pellets and can be used as a suitable feed stock as partial substitution to scrap in EAF. It offers benefits like guaranteed uniform and predictable composition containing low amounts of sulphur, phosphorous & tramp elements along with environmental friendliness during usage. The typical composition of sponge iron is shown in Table 1.

TOTAL Fe	87% - 94%	P	0.007% - 0.05%
METALLIC Fe	76% - 89%	SiO2	2% - 4%
METALLIZATION	86% - 93%	Al2O3	0.60% - 2.7%
C	0.20% - 2.4%	CaO + MgO	0.2% - 3%
S	0.01% - 0.03%		

Table 1 - Typical composition of sponge iron

Coal based sponge iron has carbon content of 0.25% and metallization of 90% while gas based sponge iron has carbon of 1.6% and metallization to the tune of 93%.Sponge iron has bulk density of 2 – 3.3. t/cu.m. and is higher than that of most scrap. The actual density is more than that of slag in the furnace to facilitate sponge iron melting at the slag/metal interface.

When sponge iron is used, there is a need to reduce the iron oxide and to neutralize the acid gangue. The reduction of 1% iron oxide requires approx. 2.3 Kg of carbon and 12 Kwh/ ton of liquid steel. The neutralization of acid gangue (Al_2O_3 + SiO_2) requires 20 Kg of lime and power to the tune of 11 Kwh/tonne of liquid steel to achieve required slag basicity.

Continuous charging is the widely practiced method wherein charging starts after creation of partial molten pool in the bath and is continued through the charge bins provided along the roof. This charging system enables better distribution of charge with improved bath heat transfer and slag-metal mixing. It lowers heat losses and help in producing stable arc with improved productivity and up to 80% DRI in the charge can be successfully fed through this method.

The optimum benefits are generally believed to be attained when the melting of DRI takes place at the slag/metal interface which necessitates appropriate feed rate. The feed rate further is dependent on the chemical composition of DRI and the bath temperature. Generally, feed rates of 27 to 35 Kg/min./MW of applied power are maintained. However, higher the metallization (optimimum required level is 93%), lower is the power consumption and higher yield which necessitates carbon injection systems to take care of metallization problems. It has been observed that for every 1% decrease in metallization, the increase in power consumption is to the tune of 18 Kwh/ ton. Productivity about 1 ton per hour is reported for every 10% increase in DRI usage.

There has been a new trend in continuous feeding of hot DRI with temperatures of 500ºC - 600ºC for the units which has accessibility to DRI furnace. Introducing hot DRI surge bin between the DRI furnace and EAF, up to 80% DRI in the charge is successfully fed. With hot DRI charging, the effect of metallization is compensated by the temperature of DRI itself thus possessing high potential in saving energy. This practice can reduce power consumption by 20 Kwh/T of liquid steel for each 100ºC increase in composite charge temperature. Energy savings of 105 Kwh/t for 80% DRI charge compared to 52 Kwh/t for 40% DRI charging have been reported. Electrode consumption gets reduced by 30% when continuous feeding of DRI as it produces stable steel bath reducing the possibility of electrode breakage , compared to the conventional 100% cold scrap charge practice. This is due to higher productivity, decreased electrode oxidation, less frequency of roof opening meaning less thermal shock, less CO in furnace atmosphere and less electrode breakages.

Hot metal (Liquid Pig Iron)

This is a low cost metallic feed for EAFs which have access to blast furnace or cupola. The typical composition of hot metal is shown in Table 2.

C	Mn	Si	P	S
3.75%	0.48%	0.85%	0.18%	0.035%

Table 2 - Typical composition of hot metal

The sensible heat of molten pig iron at the melting point is around 1084 MJ/mg. Assuming the heat efficiency of EAF at 80%, this heat will be equivalent to about 1350 MJ/mg (375 Kwh/Ton) of liquid pig iron. It is estimated that 1 Ton Hot Metal + 25 Kg Lime = 0.92 Ton of clear scrap + 40 Kg of carbon + 330 Kwh. To derive maximum benefit from the addition of liquid pig iron, it is necessary to look at parameters like the composition of the charge mix, thermal condition of the charge at the time of hot metal addition and proper melting practice to take care of high phosphorous and carbon.

Hot metal is added in EAF through spout ladles after roof opening. It is added after partial melt formation in EAF. If hot metal addition is carried out to a full melted over oxidized steel bath in EAF, reactions occur leading to violent boiling. Hot liquid metal if added soon after power on, in contact with cold scrap immediately freezes due to chilling effect. Hence, addition of liquid metal on sufficiently heated scrap seems to be the most efficient charging practice. This is because, as the scrap gradually melts, the already liquid pig iron gets refined under the action of iron ore and lime in the charge.

The amount of hot metal to be charged depends on the grade of steel to be made and the amount of oxygen deemed efficient. Successful hot metal practices reveal usage to the extent of 60% of the total charge. The major problem with hot metal is dephosphorization of the melt in EAF. This is taken care through addition of sufficient amount of iron ore in the charge that facilitates high FeO (15% - 20%) and 75% dephosphorization before oxygen blow at melt down stage. Carbon is removed by iron ore partially and the required level of carbon achieved through oxygen injection at high rates. It is noticed that hot metal poses no problem with regard to quality requirements of carbon and low alloy steels. Energy savings of 130 Kwh/T, increase in productivity by 25% and reduced electrode consumption by 15% are achieved through use of 60% hot metal in the charge.

Hot metal + Sponge iron

The new trend for cost effective production processes in EAF is combined use of hot metal and coal based sponge iron by completely substituting scrap. With hot metal usage, initial slag of EAF has low FeO content unless sufficient amount of iron ore is charged which makes the slag viscous leading to poor phosphorous removal and poor arc efficiency caused by non-foaminess of the slag. Due to high carbon in hot metal, the decarburization rate requirement is as high as 0.25% C/min which limits its usage in EAF due to low depth/volume ratio. By continuous feeding of coal based DRI, dephosphorization becomes faster and FeO of DRI promotes foamy slag promoting decarburization thus reducing oxygen blowing time. Even, increase in yield to the tune of 2% achieved compared to 80% DRI method.

The various practices followed are usage of hot metal between 40% to

60% and the remaining with DRI. Productivity improvement by 50%, energy savings of 200 Kwh/T and electrode consumption reduction by 40% have been reported through this method.

Low cost energy inputs

As energy accounts for around 12% of the production cost, there is an increasing trend in application of oxygen as chemical energy input for reducing energy consumption. Today, oxygen to the tune of 30 Nm^3/t is being used in many EAF units in the world to reduce melting time & power consumption coupled with recovery of energy through CO post combustion. Moveable oxygen injection systems like submersible hand lance, consumable pipe manipulators, water cooled lances or retractable burners and fixed oxygen introduction systems like oxy-fuel burners, supersonic jet burners, carbon injection lance with oxygen and virtual lance burners are widely used. Savings in energy is about 3 Kwh/Nm^3 oxygen per ton of liquid steel when one kg of coke is added in EAF. Evolution of these technologies helped to meet 10% energy requirements and productivity improvement of around 8%.

Ultra high powered furnaces

It is a well known fact that higher the rate of power input, higher the thermal efficiency due to reduction in time dependant heat losses. This resulted in development of Ultra High Powered EAF units with rating of more than 700 KVA per ton. However, higher rate of power increases arc current which would increase electrode tip erosion. Hence, with higher power input, the applied voltage has to be more which can be achieved through use of longer arcs. These longer arcs led to high refractory erosion. To take care of this problem, water cooled panels were developed to replace much of the furnace side wall and roof refractory. Though the application of panels drastically reduced the refractory consumption, the heat losses increased which made EAF steel makers to splash molten slag for improving thermal efficiency. Other developments that took place to counter the long arc operation include foamy slag practice. In this practice, carbon and oxygen are injected in bath increasing the slag cover depth from 0.1 m – 1.0 m acting as additional energy burying the arc and improving thermal efficiency. The process led to power savings to the tune of 40 Kwh/T along with better slag deoxidation.

Bath stirring

This development helped to absorb the high power inputs presently in use coupled with savings in yield to the tune of 5 Kg/T and energy about 14 Kwh/T. Also, bath stirring resulted in producing slag with low FeO & MnO contents decreasing aluminum consumption.

Slag free tapping systems

Slag free tapping technologies evolved for improvement in steel quality and also productivity through low temperature tapping and shorter tap duration. Eccentric Bottom Tapping process is the one where the bottom half of the furnace is fitted with eccentrically located tap hole by widening the tapping area and removing the conventional spout. Submerged Tap Hole method is a modification to the conventional tap hole with the tap hole spout extending the hearth profile allowing steel tapping without vortexing. Though, this process is cheaper and efficient, the tapping times and temperature losses are in excess compared to other techniques. Slide gate Tapping technique is a hydraulically operated linear sliding gate valve mounted on the outlet tap hole of the furnace. Here, the slide gate remains in open mode throughout the melting period and the tap hole is filled with filler material by use of pusher rod with the filler material removed prior to tapping by scoop device or by mild oxygen lancing. In this technique, the gate valve is closed once slag just starts coming in. The benefits accrued through these systems include production of low "P" steels, extra low "S" steels, decrease in treatment time of secondary refining units and reduced aluminum consumption.

Automation systems

Computer assisted steel making has evolved through development of sensors and programming of power input, charging practice, amount of oxygen lancing and adjustments of chemistry during melting & refining. Process control equations through programming are applied for assessing the overall furnace performance as well as calculating requisite amounts of oxygen and power input for achieving the desired tapping conditions for carbon and temperature. Least Cost Mix programmes are developed with process cost elements like yield, time and energy as a means to cut down costs.

Conclusions

Continuous developments has reshaped EAF steel making process to meet the steel requirements of the world. Modifications are still on in EAF to bring in further improvements in productivity, energy economy, application of cheaper metallic feeds, reduced electrode & refractory consumption to make EAF as the lowest cost steel producing route in the world. ❑❑❑