Metallics for induction steel melting furnace

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Abstract

In this presentation the author has mainly considered metallics inputes for Steel/ Iron melting through Induction melting route. Induction melting for ferrous products at viable cost was unheard of two decades ago. So also the use of Sponge iron or Pig Iron as inputs for making steel was unimaginable through Induction melting furnaces route. Revolutionary changes are taking place all over the world. The factors governing evolution of process depends upon local, regional, geographical and economic considerations. A process suitable in European conditions may have to undergo changes when used in other countries or region.

1. Availability of input metallics/materials

1.1 *Steel melting scrap*

So far, steel melting scrap is the most important input in secondary steel making through Electric Arc or Induction Furnaces. However, shortage of steel melting scrap all over the world is being felt for a decade now. The factors responsible for this are (a) the increase in production of steel/alloy steels by Electric Arc and Induction Furnaces (neraly 28% of steel is produced through this process); (b) the decrease in generation of scrap at Primary Producers' plants due to Con-cast process for making long as well as flat products; (c) the use of steel scrap by Special Cast iron producers; and (d) use of steel scrap of primary producers in LD converters as coolant. Under these circumstances alternate materials/metallics have to fill in the gap. The use of Electric Arc and Induction furnaces for production of steel will continue. Indigenous Steel melting scrap in India is in short supply and Steel scrap is being imported. At one time, nearly 2.5 million tonnes of scrap was imported. However, in the last 5 years imports have declined mainly due to recession in demand resulting in reduced production of steel by EAFs & IFs. The international price of steel melting scrap has increased considerably making it unviable to import.

1.2 *Pig Iron*

In recent years it is noted that smal/ quantities of pig iron is used by Electric Arc and Induction furnaces along with steel scrap. Quite a large capacity has been installed for making pig iron by mini-blast furnaces in India. There are plans to make steel by using

LD converters as well as Electric Arc Furnace. It can only be used in combination with sponge iron and steel scrap in small proportions. The Secondary Steel manufacturers are not likely to use Pig iron in large proportions in the near future.

1.3 *Cast iron scrap*

Cast iron scrap is being used both by Electric Arc Furnace as well as Induction Furnaces. The advantage of its lower melting point is taken to form a pool of liquid metal. However, now-a-days greater quantity is used in combination with sponge iron. Cast iron scrap of various categories is available in all parts of India to meet demand for Secondary Steel making industry.

1.4 *Direct reduced iron*

Direct reduced iron are two types according to the process of their manufacture. The first type is called Sponge iron (S I) which is manufactured by solid reduction process using coal as reductant either with or without liquid fuel oil. The second type is called Hot Briquetted Iron (HBI) which is manufactured by gaseous reductant process using natural gas. In view of shortage of steel melting scrap the secondary producers have to depend on DRI for metallics to make steel. According to sponge iron Manufacturers Association of India the installed capacity in 1994-95 will be 5.5 million tonnes.

The production of DRI in 1993-94 was nearly 2.2 million tonnes and about 8 lakh tonnes of HBI was exported by ESSAR-Gujarat, the leading HBI producer in India. It is felt that considerable quantity of DRI will be indigenously available to meet indigenous demand of metallics of Secondary Steel producers.

2. **Characteristics of input metallics/materials**

2.1 *Physical*

2.1.1 *Heavy steel melting scrap*

Heavy steel melting scrap is available from pieces to big lumps and odd shapes. Old discarded articles lying at remote places pose a problem of recovery particularly in countries where manual labour is costly. In some countries which were part of the USSR, large quantities of such scrap is available. The authorities in those countries say that anybody can take the scrap free or on nominal payment. There is no serious thought given by these countries to dismantle heavy machinaries, ships etc., and use it for remelting. In the USA they have heavy shredding machines where automobile bodies, drums and other machines made of sheet/plate metal are pressed under heavy presses and shredded pieces of 2 to 3 kg. are obtained. India has been getting such scrap in the past. Mill-cut ends are the best remelting scrap.

2.1.2 *Light melting scrap*

Turnings and borings from Engineering Workshops are collected by local traders. If melting furnaces are located in the same area, such scrap is directly delivered to melting units. But for delivery to far away places, the turnings and borings are crushed and compressed to reduce volume. There is more melting loss on turnings and borings comparing to Heavy Steel Melting Scrap. Rusted turning and borings give still higher melting losses. Due to shortage of scrap and good price realisation mostly workshop dispose the process scrap at the earliest.

2.1.3 *Old cans, containers made of sheets & plates*

The sheet metal containers have some coatings. These can be paints, apoxy coatings; metallic coatings such as galvanising, tinning, aluminising or plastic coats. The first operation is to remove the coatings as much as possible. This is achieved by mechanical; chemical or thermal treatments. If not removed, it may lead to (a) burning losses, (b) greater volume of slag formation; (c) more heat losses and (d) poor yield. The cans or containers are sheared, pressed and then shredded to make them denser. This scrap is cheaper than other types. However, since carbon content is low, this scrap can be used for diluting opening carbon of bath.

2.1.4 *Automobile bodies and railway scrap*

While in Western countries and USA very heavy shredding machines are available, no such treatment is done to automobile bodies. Firstly, the quantity of automobile discard is very low in India at present. Secondly, the work of cutting, shearing and bundling is done by cheap manual labour. But the time is not far when big shredding machines and presses would be needed for automotive bodies in India due to increase in the population of vehicles. Railway scrap is mostly used by rollers and forging industries. Except coach bodies or wagons of goods trains, other railway scrap is medium carbon steel and unsuitable for making mild steel. However, forging quality steel can be made by melting the scrap in induction melting furnaces.

2.2 *Cast iron scrap*

Cast iron scrap coming for melting is from old machine parts, ingot moulds and brake shoes of railways. These are in the form of lumps and can be broken manually to render proper size of scrap for charging in furnace. Advantage is taken of its low melting point to form initial pool of molten metal.

2.3 *Pig iron*

Pig iron is also used for the same purpose as C.I. However, experiments are being made to use pig iron in Eléctric Arc Furnaces to make steel.

2.4 *Sponge iron & hot briquetted iron*

As far as hot briquetted iron is concerned, it is in briquette form. Bulk density varies from 2.5 to 2.7 mt/m^3; Apparent density is 5.1 to 5.5 gms/cm^3; nominal weight is 0.5 kg. of one briquette; nominal size is 110 mm x 50 mm x 30 mm and finally size distribution is +6mm to 200mm. Due to high density, the charging in furnace is easier and melting is faster. Sponge iron obtained by solid reduction process is available in small pieces of weight from 50 gms to 100 gms like broken stone angular type. They also do not pose any proble in charging and melting. However, fines rendered from HBI and SI require more melting time and if bath is not manipulated properly or sequential charging is not done, choking in furnace may occur. Eroding of the lining will also take place.

3. **Chemical compositions**

3.1 *Steel melting scrap*

Since steel melting scrap is a waste of steel products (earlier manufactured by main producers) during process of fabrication of steel items it will have chemical constituents of the parent steel. Due to use of various types of scrap by remelting industries, the scrap may contain tramp elements like Cu, Ni, Sn and Mo etc. The excessive presence of these elements in steel affect mechanical properties of final product made by induction melting furnaces. Alloy steel scrap should not be mixed with mild steel scrap. As stated in para 2.1.4 scrap with coating introduces undesirable elements such as S, P, Zn and Pb. Sometimes aluminised articles may also be refined, in Induction furnace refining action cannot be carried out. It is, therefore, desirable that all such scrap is treated before use. De-tinning, De-zincification and chemical removal of coating is done along with drying de-oiling and burning away the grease etc. Besides introducing S and P, oily or wet scrap may lead to introduction of Hydrogen in steel.

3.2 *Cast iron and pig iron*

In such scrap the carbon varies from 2.5 to 4%; Silicon is from 1.5 to 3.0%; Sulphur is 0.04 to 0.,12%; Phosphorous is 0.25 to 1.00% and Manganese is less than 1.0%. It has a melting point near about 1200^{0}C. It melts very fast in furnaces. Refining for S and P cannot be done in IF except in small proportion or by using a separate vessel. However, it is not a basic material for making steel in IFs and these elements can be diluted or refined. But melting of C I and pig iron should be in limited quantities. It is learnt that in EAFs, Steel can be produced through pig iron route.

3.3 *Sponge iron or HBI*

Considerable quantity of Sponge iron (DRI) and HBI is being used in IFs. DRI has Fe (total) from 90 to 92% and metallisation is also 90 to 92%; Carbon is 0.18 to 0.2%; P is from nil to 0.06; and S is 0.015 to 0.04. HBI has Fe total 93% and Fe metallic is 86.5% and metallisation is 93%. Carbon is 1.2%. Sulphur is 0.015 max. While melting of HBI, the slow boil which results from reaction of FeO with C, purges the liquid Steel of dissolved gases and reduces carbon. The advantage of using HBI is that not only higher carbon of HBI is reduced, the carbon of bath (while melting scrap) is also reduced. Thus sponge iron and HBI are used in adjusting carbon of steel scrap.

4. Input charge blending

4.1 *Chemistry*

From the foregoing paragraphs, it is clear that the input material for IFs. are (a) basic steel melting scrap, (b) cast iron and (c) sponge iron of HBI. Taking chemistry into consideration steel melting scrap offers maximum advantage as it is 100% Fe and other elements are in desired level. But some scrap may have elements in higher percentages. Thus, it is necessary to make the charge mix. As stated earlier cast iron is used to make pool of initial metal but now-a-days with greater use DRI and HBI, more of CI scrap can be used because in SI or HBI other elements are much less and the final bath chemistry can be made up as needed for mild steel or other types of steel.

4.2 *Considerations other than chemistry*

In addition to getting final product of desired chemical composition, economics of using input materials is necessary to assess. In case, steel melting scrap is available at a cheaper rate and melting to make final product is cheap, DRI or HBI will not be used. However, conditions in India vary very much at the same location. Suddenly supply of steel melting scrap is reduced due to less quantity of imported scrap or lesser generation of scrap in the area or region. In 1991, SI and HBI prices were suddenly jacked up by Rs. 2000.00 per tonne over a period of 4 months due to shortage of scrap. But now due to greater production of DRI and HBI ruling prices are favourable to substitute steel melting scrap by DRI.

4.3 *Conversion cost*

Taking into consideration price of pencil ingots in the market or equivalent size billets marketed by main producers, one has to work back the economics of using scrap, CI and DRI. If the price of scrap is taken as Rs. 7,000 per tonne (average) including melting loss as 5%, the conversion cost is minimum Rs. 3,500 per tonne. It would mean that Pencil ingot is to be sold at minimum Rs. 10,500 per tonne plus excise duty of 15% which comes to Rs. 1,575. Price therefore, has to be Rs. 12,075 per tonne. However, the market selling price of Pencil ingots with Excise Duty is from Rs. 9,500 to Rs. 10,600 per tonne at various locations in India which is much less than cost of raw material plus conversion cost plus excise duty. In case DRI or HBI is used, more slag will be generated, power consumption increases, refractory lining life is decreased and yield is less as tap to tap time is increased. Thus, techno-economic considerations govern the use of alternate materials.

4.4 *Charge blending*

Chemistry is the primary consideration in making a charge mix. Cost of input material is next to be evaluated and finally the conversion cost is taken into account. In addition to all these, various types of steel melting scraps are to be mixed properly and charged according to physical characteristics , ease of melting and less melting losses. In some northern States, the ratio of charge mix at present is as follows :

Sl. No.	Metallics used	(%)	Cost of conversion Rs./tonne
I.	Steel scrap	60	
	SI or HBI	25	
	C.I. or Pig iron	15	
	Yield is 92% (max.)		3700
II.	Steel scrap	50	
	SI or HBI	30	
	C.I. or Pig iron	20	
	Yield is 90.5% (max.)		4100
III.	Steel scrap	25	
	SI or HBI	25	
	C.I. or Pig iron	50	
	Yield is 88.0% (max.)		4500
IV.	SI or HBI	80	
	C.I. or Pig iron	20	
	Yield is 84% (max.)		5000

The charge blending will depend upon

1. Cost of raw materials (inputs)
2. Power Cost
3. The market price realisation
4. Quality of Steel to be produced.

5. Charging practice of input materials

5.1 While melting the charge, correct charging practice is very important. Due to different types of scrap, CI and DRI or HBI available to the manufacturer, initial trials may be conducted to make the charge mix and then to establish best practice of sequence of charging. Normally induction furnace scrap mix consists of shredded scrap, commercial scrap, MS turnings and borings cast iron scrap, cast iron turnings and borings.

5.2 *Sequence charging*

5.2.1 First charge CI scrap in I.F. according to pre-determined percentage. It will melt fast and will give high melting yield to Sponge Iron.

5.2.2 It should be followed by Heavy Melting scrap so that maximum power is drawn from transformer and to reduce melt time.

5.2.3 Turnings and borings in compressed condition is best to charge next and melted.

5.2.4 If HBI or DRI is used, it is added in sequence with commercial scrap depending upon percentage of DRI or HBI used as per trial reports.

5.2.5 Distribution of charge in furnace must be ensured.

5.2.6 Most of SI of HBI should be charged by the time the furnace is 50% with liquid metal. At this stage slag should be removed by spoons or tilting the furnace. Removal of slag is important so that it does not damage the furnace lining.

5.2.7 Again DRI or HBI and scrap be charged in alternate sequence. If slag formation is more, it should be removed side by side of melting operations. All DRI or HBI charging should be completed by the time furnace is having 75% liquid metal.

5.3 Case studies as carried out by ESSAR are given in Table-1.

6 New developments

6.1 *Increasing use of DRI & HBI in IF*

Besides economic considerations, the use of DRI and HBI is restricted primarily due to deterioration of refractory lining during melting. This is due to slag eroding/ corroding the silica lining. If the lining is broken, the liquid metal will penetrate and damage the induction coil which is very costly. Therefore, our aim is not to allow slag becoming thick or remaining for a longer period in furnace. It should be removed manually by spoons. Work is going on to develop mechanised system of removing the slag by grabbing it with the help of crane. In case IFs are designed for backward tilting, removal of slag can be done more conveniently.

6.2 *Use of iron carbide*

Nucor Corporation has developed iron carbide as a substitute raw material in EAFs and IFs. Iron carbide consists of 93% Fe_3C; 4% iron oxide; 3% gangue. In production of Fe_3C, iron ore fines are used which have a lower cost than pellets or lumps ore. Iron carbide is not pyrophoric and the product readily dissolves in liquid steel and can make energy contribution to EAFs. Fe_3C eliminates or reduces carbon injection. It has a scrubbing action in the steel bath and reduces nitrogen which is needed for high quality steel. Among steel scrap substitutes iron carbide is likely to take its place in future.

7. Trends in the steel melting scrap availability

7.1 Steel melting scrap is the most recycled material in the world. It is not highly regulated and has freely responded to economic laws of supply and demand. Due to improved production in integrated steel plants, the generation of revert scrap is reducing constantly. It is predicted by world authorities that there will be shortfall of metallics for steel industry for next 15 years. This may lead to recovering more obsolete scrap and using substitute materials such as sponge iron and pig iron IFs. The substitute materials used at present is only 6.5% of the scrap requirement in the world. But it is likely to increase to 10% in next 7 or 8 years.

7.2 The world scenario is changing fast. More and more direct reduced iron is being produced in the world. India is emerging as a leading DRI and HBI producing country. In 1994-95, the production of HBI and DRI is likely to be 4.5 million tonnes. It may reach a level of 6.5 million tonnes in 1997-98, and 8.00 million tonnes by the end of this century. India is not to worry about availability of METALLICS for EAF and IFs by end of this century provided prices of sponge iron remain low and realisation on products of EAFs and IFs are sustainable. However, IFs have to adopt technologies to suit use SI and HBI more and more.

Table-1 : Essar HBI melting results in induction furnace

Case Study	*A*	*B*	*C*	*D*
F/C size (ton)	5	5	5	5
Rating (KW)	2500	2500	2500	2500
HBI addition	10%	14%	16%	25%
Head time (Min)	110	110	110	115
Ingot carbon	0.18%	0.17%	0.19%	0.14%

Case Study-A

Replacement of heaving scrap with HBI furnace size - 3 ton		
Average HBI addition	26%	38%
Average Heat time (min.)	95	98
Average power consumption (KW/H/T)	636	645
Ingot carbon	0.23%	0.19%
Ingot sulphur	0.045%	0.040%

Case Study-B

Replacement of commerical scrap with HBI		
Furnace size - 8 ton		
Average HBI addition	26%	40%
Average LM yield	86.4%	87.9%
Average power consumption	621	642

Case Study-C

Replacement of heavy scrap with HBI furnace size - 3 ton		
Average HBI addition	26%	49%
Average heat time (Min.)	94	92
Average power consumption (KW/H/T)	621	649
Average LM yield	89.9%	89.3%