Indian Sponge Iron Industry – An Overview

- Sanjay Sengupta

Although the BF-BOF route of iron and steelmaking accounts for about 65 percent of global production of crude steel, the process requires various treatment of raw material, involving high capital cost and substantial investment on infrastructure. It also leads to environmental problems and has a long gestation period.

To find a way out of these shortcomings of BF-BOF process, EAF steelmaking was introduced long ago. The increasing trend in the prices of steel scrap and its short supply, led the steel technologists to find a suitable charge materials in EAFs in the form of Direct Reduced Iron (DRI).

Sponge iron or DRI is obtained from the direct reduction of iron ore. The shape of the ore or agglomerate remains unchanged due to the removal of Oxygen, leaving behind a honey combed microstructure which has suggested the name 'Sponge Iron'.

The direct reduction process have some basic advantages which are mentioned below :

- They are easily adaptable to small as well as moderately sized steelmaking plants / units.
- Their capital cost requirement is low
- They can work with off-grade raw materials
- They can utilise small sources of iron ore near the steel plants, thus reducing transportation cost
- Their products are of uniform size and contains low levels of tramp metallic elements.

Raw Materials for DRI Production

The major raw materials required for sponge iron production are Iron Oxides in the form of lump ore, pellets, non-coking coal (with high reactivity) and fluxing materials like lime and dolomite.

Some precautions are necessary in selecting the Iron Oxide specially its Phosphorous content and its reliability for easy reduction. Use of high purity pellets with low phosphorous content at economic price helps in the cost-effective production of sponge iron of desired quality.

Chemical Composition of Internationally Trade HBI

The usual chemical composition of internationally traded HBI is given below :

Parameters	% of Content
Total Fe-Content	93-95
Metallic Fe-Content	85-92
Degree of Metalization	92-95
Carbon	1.0 – 1.5
Sulphur	0.02 – 0.15
Silica	1.00 – 2.00

For maximum yield, the metallic iron content should be at highest possible level with sulphur and phosphorous as low as possible. The gangue content should preferably within 2 percent and silica less than 2 percent to ensure lower slag volume, lower power consumption and for achieving higher productivity.

Three Forms of DRI

There are three forms of DRI shown below:

- Cold DRI (CDRI)
- Hot DRI (HDRI)
- Hot Briquetted Iron (HBI)

Cold DRI (CDRI)

After reduction, the DRI is cooled in the lower part of the shaft furnace (for gas-based) to about 50 degree centigrade or cooled in the other Kiln (for coal based) to about 80 degree centigrade. The material is typically used in a nearby EAF and must be kept dry to prevent reoxidation and loss of metallization. CDRI is ideal for continuous charging into the EAF.

Hot DRI (HDRI)

HDRI can be transported to an adjacent EAF (within the plant) at temperature up to 650 degree centigrade to take the advantage of the sensible heat content of HDRI, which helps to increase productivity by reducing the consumption of electricity and production cost. There are three methods used for the transportation of HDRI :

- Hot Transport Conveyor
- Hot Transport Vessels
- HOT LINK

By charging HDRI, electricity savings are 20kwh/t of liquid steel per 100 degree centigrade and the process increases productivity upto 20 percent.

Hot Briquetted Iron (HBI)

HBI is made by compressing hot DRI discharged from the shaft furnace of about 650 degree centigrade into PILLOW shaped briquettes.

HBI is the preferred DRI product because it is much denser than CDRI, which reduces reoxidation rate. This enables HBI to be stored and transported without special precautions. HBI is produced from natural iron ore with no additives or binders. It is a source of clean, highly metallized iron units.

The heavy mass of HDRI easily allows penetration of the furnace slag layer as its density is greater than 5.0g/cm3, which allows for rapid penetration of the furnace slag layer which has a density less than 3.0g/cm3.

Major operational advantages of using HDRI are as follows :

- Well defined consistent chemistry with guaranteed specifications
- Low residual content (Cu, Ni, Cr, Mo, Sn, Pb and V)
- Dilutes impurities in lower quality scrap
- Promotes foamy slag and reduces nitrogen level in EAF
- Shields refractory to reduce damage.
- Increases iron production in BOF, reduces coke rate and CO2 emissions
- Metallic yield in BOF similar to hot metal
- Higher thermal and electrical conductivity for faster melting
- Lesser fines generation gives added value to the customer
- It is 100 times more resistant to re-oxidation than conventional DRI and picks up 75 percent less water.

In India, the hot DRI technology is the innovation of Essar Steel Ltd. And saves about 12 KwH of energy per tonne of DRI consumed by EAF with the utilisation of 650 degree centigrade heat contained in the iron.

Continuous Feeding of DRI

Continuous feeding of DRI into an EAF results in achieving high power level than 100 percent scrap charge with similar settings in the furnace.

Due to the heterogeneous nature of steel scrap and the continuously varying arc lengths between the electrode and scrap leads to wide fluctuations in the melting scrap. It has been found that such wide fluctuations reduce the effective power input. On the other hand, the melting of continuously fed DRI has been found to result in an increase of saving power up to 15 KwH per tonne DRI produced with the use of UHP transformers. Ultra High Power (UHP) transformers help to achieve better thermal efficiency which facilitates fast melting of Hot DRI charge. Use of UHP transformers results in increased productivity and as mentioned above, effects a saving in power consumption up to 15 KwH per tonne of DRI produced.

Use of DRI in BOF

HBI in the form of DRI is best suited for use in the BOF because of its bulk density and physical strength. It is a preferred alternative to scrap due to the following reasons :

- Residual levels are lower
- Bulk density is higher
- Mass and heat balances are more accurate
- Steel chemistry is easier to control

Besides the above, other advantages of charging HBI in the BOF are as follows :

- It acts as a coolent
- There is no sculling on the lance
- HBI can be used for low sulphur steels
- HBI has much lower tramp materials. It is non-pyrophoric.

It is free from tramp materials like copper, zinc, chromium, tungsten, molybdenum etc. that are usually present in steel scrap.

Use of DRI in Ifs

The use of DRI in the charge-mix of Induction Furnaces (IFs) commenced in the early nineties of the last century, sponge iron manufacturers in India trained the IF technologists about the proper use of DRI in the IFs. Many sponge iron manufacturers have installed IFs and are using 60-70 per DRI in the charge-mix.

Technologically, for good quality steel production emphasis should be given on:

- Good weldability
- Proper balancing of charge-mix for controlling the tramp elements.
- Correct carbon equivalent
- Correct addition of alloying elements to achieve the desired mechanical properties
- Control of sulphur and phosphorus conforming to 151786

Use of DRI in EAFs

Due to the low availability of indigenous steel scrap and its high price, DRI is being used as a supplement in the charge-mix of iron production during the last few decades. Initially, the DRI was being used for producing low cost carbon steel long products where scrap supplies were limited.

During the last two decades, EAF steelmakers have experienced the true value of DRI as a scrap supplement that dilutes undesirable contaminants in the charge-mix when the EAF is used to make high quality flat products and low nitrogen steels.

DRI is ideally suited for use either as a replacement or a supplement for scrap in the EAF. DRI provides EAF operators to regulate their furnace charges to achieve the desired product quality at a lowest cost per tonne of liquid steel.

There are two major benefits of charging HDRI into an EAF. These are:

- Lower specific electricity consumption
- Increased productivity up to 15-20 percent

The energy savings occur as less energy is required to heat the DRI to melting temperature which shortens the melting time with utilisation of 650 degree centigrade heat contained in the HDRI. Other benefits like resistance to re-oxidation etc. have already been mentioned.

Some of the major steel producers in India are charging about 80 percent of DRI in the charge-mix. Benefits / savings of using Hot DRI in Electric Arc Furnace vis-a-vis cold DRI are shown in Table-1.

TABLE – 1 : BENEFITS / SAVINGS OF USING HDRI IN EAF VIS-A-VIS CDRI

Parameters	Units	CDRI	HDRI
Electrode Consumption	Kg/t	2	1.8
Oxygen Consumption	Nm3/t	32	32
Energy Consumption	Kwh/t	640	520
Tap to Tap Time	Minutes	82	68
Productivity	t/h	184	221

Source : JSPL

It is evident from the above table that use of HDRI in EAFs saves energy consumption by about 19 percent per tonne of DRI produced and productivity increases by more than 20 percent.

Growth of Sponge Iron Industry in India

Sponge Iron India Ltd. (SIIL) was the first sponge iron plant in India which was set up with an initial capacity of 0.03 Mtpa at Paloncha, Andhra Pradesh in 1980. It was a coal-based SL-RN plant marketed by LURGI India Ltd. Since coal was adequately available at that time, production of sponge iron by coal-based route was considered a feasible option. The growth of sponge iron industry in the country up to 1984 was however constrained by the restrictive licensing policy of the Govt. It was only after abolition of licensing in 1985, the industry started to expand.

In the late eighties of the last century, the Indian producers became enthusiastic towards setting up gas-based projects due to the discovery of large scale reserves of natural gas in the country.

The first gas-based sponge iron plant was built by Essar Steel Ltd. at Hazira in Gujarat in 1990. Essar installed MIDREX technology. The first MIDREX Mega mod plant in the world was installed by Ispat Industries Ltd. at Dolvi in Maharashtra in 1994. Grashim's Vikram Ispat Sponge Iron Plant (now Welspun Maxsteel Ltd.) was set up with an initial capacity of 0.9 Mtpa at Salav in Maharashtra. It was globally the first sponge iron plant to install HYL III technology. It started its commercial production in 1993. According to HYLSA, this was the first zero KwH plant in the world.

Industry Structure

About 330 plants / units exists which produce DRI. Three of them are gas-based while others are coal-based. The three gas-based DRI plants are located at Hazira, Gujrat (Essar Steel), Dolvi, Maharashtra (JSW Ispat), Salav, Maharashtra (Welspun Maxsteel – formerly Vikram Ispat).

Coal-based sponge iron units are located in clusters. The major clusters are Siltara (Chhattisgarh, Kaurmunda (Odisha), Saraikela-Kharswan (Jharkhand), Jharasguda (Odisha), West Medinipur and Bankura (West Bengal) and Bellary (Karnataka).

Approximate capacity wise distribution of coal-based plants are as follows:

Capacity	% Share in Capacity
Up to 30,000 TPA	18
30,000 – 60,000 TPA	5
60,000 – 100,000 TPA	2
10,000 – 150,000 TPA	9
Over 150,000 TPA	66
Total	100

A comparative analysis of the various parameters of production of DRI by Gas-based and Coal-based routes is shown in Table – 2.

India's Production of DRI

India is the highest global producer of sponge iron (DRI) since 2003. India's DRI production between 2007 and 2015 are shown in Table-3.

A downtrend in production of DRI is noticed since 2011 except in 2014. The major reasons for the decline of DRI production may be summed up as follows:

(i) Inadequate availability of raw materials

Gas-based Projects

Natural Gas is the main raw material used in the DRI production of gas-based projects. The production of natural gas in India declined from 52 billion cubic meter in 2010-11 to about 38 billion cubic meter in 2013-14. Against a requirement of 8mmscmd, the allocation for the three gas-based projects was 0.725 mmscmd in 2013. Capacity utilisation of gas-based projects in 2014-15 was only 25 percent.

Coal-based Projects

In 2014-15 production capacity of sponge iron through coal-based route was 36.03 Mt and the production through this route was 14.41 Mt in 2014-15. The production of coal-based DRI is declining due to the following reasons:

(i) Shortage of iron ore due to various legal restrictions which led to decline of production in Goa, Karnataka and Odisha.

(ii) Coal-based projects suffered from inadequate supply of non-coking coal of desired quality from Coal India Ltd. (CIL). CIL supplied only about 20Mt of coal as against a requirement of 50 Mt based on the capacity of coal-based projects as on 31.03.2014.

Shortage of raw materials as well as environmental problems has compelled many coal-based DRI units to close down. Capacity utilisation of coal-based DRI plants/units came down to 50 percent in 2013-14 against 67 percent in 2010-11. Present capacity utilisation of coal-based units stands at about 40 percent.

Innovations in DRI Production through Gas-Based Route

Production of DRI through gas-based route without using natural gas has been an unique and outstanding development in India's DRI production history. Two of such developments are mentioned below:

(a) JSPL's Syngas DRI Plant at Angul

JSPL's DRI plant at Angul, Odisha is a designed MIDREX DRI plant with a capacity of 1.8 Mtpy. This is first plant in the world paired with commercially available technology of coal gasification to produce DRI with synthesis gas.

The Syngas technology has been claimed as the future of coal-based DRI production because it allows all the benefits like quality and reliability of the DRI process by using coal as the primary energy source rather than natural gas.

In case of rise of energy costs, coal

TABLE – 2 : COMPARATIVE ANALYSIS OF VARIOUS PARAMETERS OF GAS-BASED AND COAL-BASED PRODUCTION ROUTES OF DRI

Parameters	Gas-based DRI/HBI	Coal-based DRI
Metallisation (%)	Upto 93	92 (max)
Carbon (%)	1.2 to 2.5	0.2 to 0.25
Stability	Resistant to Degradation	Easily Degradable
Bulk Density, T/M3	1.6 to 2.0	1.8 to 2.5
Recitation	Prone to Re-oxidation Unless Briquetted	Relatively more Stable
Melting in EAF	High Carbon is Advantageous for Reducing Residual Iron Oxide in DRI / HBI	Extra Carbon is required for Reducing Residual FeO in DRI
Melting in BOF	Carbon content will be high	Carbon in liquid metal is reduced FeO in DRI
Non-magnetic Materials (%)	NIL	1 to 2
Yield of Liquid Steel	1-2 percent more than coal-based DRI	1-2% less than gas-based DRI/HBI
Usage in EAF (%)	Upto 80	30-60

TABLE – 3 : INDIA'S PRODUCTION OF DRI : 2007-2015 (MT)

Year	Production of DRI	% Change
2007	19.1	==
2008	21.2	10.99
2009	22.0	3.77
2010	23.4	6.36
2011	22.0	(-) 5.98
2012	20.1	(-) 8.64
2013	16.9	(-) 15.92
2014	20.4	20.71
2015	17.4	(-) 14.71

Source : WSA

gasification also enables the use of lower quality coals or waste products to produce energy. The shaft furnace at JSPL, Angul is nearly identical to the one used in natural gas-based MIDREX plants. The main difference between the traditional MIDREX flow sheet and this new combination is that it uses a coal-based synthesis gas source rather than a natural gas reformer. JSPL's Angul plant is designed with greater flexibility for production of Hot and Cold DRI.

Advantages of Syn Gas Based DRI Process

(i) Syngas based DRI process is an inherently high metallization process due to the following reasons :

- The counter-flow of reducing gas and iron oxide in the reduction furnace.
- A furnace burden residence time 4-6 hours in the reduction zone.
- The uniform distribution of reducing gas.
- The uniform descent of burden in the reducing zone.

(ii) Lower metallization and reduced fuel and power consumption, if required, are achieved by increasing the production rate relative to the flow of reducing gas to the furnace bustle.

(iii) The plant can be idled for extended periods are returned to full production in a few hours.

(iv) Most EAF steelmakers want DRI with 92-95 percent metallization and 1.4 to 1.8 percent carbon. With the Syngas based DRI process, carbon can be controlled at any desired level in the range of 1-2 percent.

(v) The process has the potential to use coal Syngases from other sources such as Coke Oven Gas or BOF gas.

(vi) The quality of the DRI produced by the Syngas process has the quality comparable to natural gas-based DRI plant

(vii) The process ensures lower air emissions.

(B) JSW Steel Uses Coke Oven Gas to Supplement Natural Gas for DRI Production

MIDREX Technologies, Inc. and JSW Steel Ltd. have announced successful completion and modification of the existing MIDREX DRI plant located at JSW Steel, Dolvi Plant (formely JSW Ispat Ltd.) to utilise Coke Oven Gas (COG) to partially replace its natural gas supply for production of Direct Reduced Iron (DRI). This is the first time that COS has been commercially used in a MIDREX Shaft Furnace to replace natural gas consumption.

Alok Chandra, CEO of the JSW Dolvi Plant said that, "High natural gas pricing within India has presented challenges to make DRI with natural gas alone. Therefore, JSW Dolvi has embarked on a way to reduce natural gas consumption with no impact on production rates, and still deliver quality DRI to our steel shop by utilising COG from on-site coke oven batteries."

The vision of the Joint CEO of the JSW Dolvi plant to use "Chemical energy of COG for production of DRI instead of its traditional use of thermal energy" has given new dimensions for going to COG use in DRI plant.

According to JSW Dolvi sources, about 20,000M3 of coke oven gas is being used in the JSW Dolvi MIDREX DRI plant on an hourly basis allowing the DRI plant to offset-natural gas equal to half of COG consumption and produce DRI at a steady rate with same product quality.

A spokesman of MIDREX has observed "By using COG as a supplement to natural gas, the JSW DRI Plant is able to take advantage of the COG reducing properties and operate with greater efficiency under a wide range of operating parameters, offering maximum flexibility to JSW's Dolvi Works."

Views of SIMA

According to Sponge Iron Manufacturers Association (SIMA), major challenge faced by the Indian sponge Iron Industry is cost competitiveness. For the survival, all measures required for cost reduction, automisation etc. were taken by the industry.

On ex-plant basis, India's cost of production is very much comparable with benchmark unfortunately, subsequent logistic cost, other various taxes and duties and high capital cost makes the overall cost at the customer end become higher than steel scrap.

SIMA has taken up the concern of steel scrap imports with the highest authority but no step has been taken to restrict scrap imports causing problem for the sponge iron industry.

Conclusion

The Indian sponge iron industry is showing a down trend in recent years. Required quantity of iron ore suited for the production of DRI is not adequately available and the supply of the desired grade of non-coking is very much limited. There has been a rapid growth in electric steelmaking through EAF and IF routes in the last decade. In India's total production of crude steel, electric steelmaking has a share of about 62 percent. A significant evolution of raw materials has emerged particularly in EAF steelmaking and the way steel is produced through this route and DRI is playing an important role in this.

In case of charging DRI in BOFs, experts have observed that these furnaces need higher size of sponge iron and can compromise on

metallisation. An interesting possibility exists where lump ore for BOFs can be treated in a sponge iron rotary kiln before charging into BOFs. The iron units in the BOFs would then comprise of an optimum mix of lump ore, sinter and sponge iron.

Use of pellets with low phosphorous content can be a boon towards increasing productivity and improving the quality of the product.

Technology in coal-based projects needs much up-gradation to control pollution and improve productivity.

The sponge iron industry is making sincere efforts to raise productivity and control environmental pollution. With the desired proactive steps from the Govt., India's sponge iron industry will see better days in future.

Acknowledgment

1. Article by S. K. Dutta published in JPC Bulletin : November, 2015

2. Article by N. M. Rao, Consultant published in JPC Bulletin – January, 2014 issue.

3. Steelworld – July, 2015 Issue.