Indian Sponge Iron Industry The Global Leader

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1. Introduction:

In the production of global crude steel, iron ore continues to be the major feed stock for BF-BOF steelmaking route which contributed 63 percent of its total production in 2004. The global consumption of iron are has increased remarkably from 986.2 Mt. in 1994 to 1222.3 Mt. in 2003. The BF/BOF process, however, requires various types of treatment of raw materials, involving high capital costs 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 process, Electric Arc Furnace (EAF) steelmaking was introduced decades ago. The share of EAF steelmaking in the global output of crude steel has increased significantly from 26.6 percent in 1988 to 33.8 percent in 2004.

The increasing trend in the price of melting scrap required for EAF steelmaking and its short supply led to the search of an alternative feedstock. The steel technologists found sponge iron (direct reduce iron) as a handy material for use in the charge mix of EAF steelmaking.

Direct Reduced Iron (DRI) is a quality metallic product, produced from iron are, pellets etc., which is now not only used in the EAF route but also in blast furnaces and other iron and steelmaking process. Hot Briquelted Iron (HBI) is a denser and compacted form of DRI designed for ease of shipping, handling and storage. DRI can be used in steel plants where the DRI reduction unit is situated at the site of the steelmaking plant. DRI is now recognized as a high quality, high purity charge material, the world over. In comparison to scrap, the use of sponge iron/HBI offers more consistency in composition, low trace elements due to its porous nature and environment friendliness. The global production of DRI has gone up almost three folds from 18.5 Mt. in 1990 to 54.1 Mt in 2004 at an average yearly rate of 13.74 percent. The developing countries of the world have a lion's have in the global production DRI in recent years. Major DRI producing countries of the world are Russia, Mexico, Argentina, Trinidad and Tobago, Venezuela, Egypt, Libya, South Africa, Iran, Saudi Arabia, India, Indonesia and Malaysia.Region wise, Asia was the highest producer of DRI in the world in 2004 followed by Central and South America and the Middle East.

2. Process Description:

Sponge iron is produced using non-coking coal by the process of reduction of iron are in a rotary kiln. The reduction is carried out in a rotary kiln of a pre-determined temperature and controlled atmospheric pressure. The input raw material such as iron ore, non-coking coal (with high reactivity) and the fluxing materials like limestone and dolomite in the calibrated sizes are fed into the Rotary Kiln with the help of weigh feeders or volumetric feeders.

Due to the inclination and rotary motion of the kiln, the raw materials more slowly from the feeding end to the discharging end. During this movement, the iron are fed along with coal is pre-heated and is reduced to DRI. The material is then discharged directly into a rotary cooler where it is cooled. The cooled product at a temperature of about 80^{0}C, is discharged from the cooler and taken to the product separation and handling system.

The product, which consists of sponge iron along with non-magnetic materials such as char etc. is screened to different size fractions and then magnetically separated by means of magnetic separators. Sponge iron is then taken to a product bin for dispatch.

3. Advantages of sponge iron Over scarp:

- ❖ Sponge Iron is a better substitute of steel scrap for steelmaking through the EAF/IF routes.
- ❖ Sponge Iron also replaces ferrous scrap as coolent in L.D. Converter. The value of DRI is measured by comparing its cost and properties with those of scrap.
- ❖ It is non-pyrophorie. It is free from tramp materials viz. Copper, Zinc, Tin, Chromium, Tungstan, Molybdnum etc. that are usually present in scarp.
- ❖ Sponge Iron has a low sulphur contents.
- ❖ The DRI process has the ability to use low grade coal that is unacceptable for conventional iron making.

4. Global Scenario:

The global steel industry is using about 28 to 30 percent of alternative iron like DRI/HBI, merchant pig iron and hot metal to produce quality steels. DRI/HBI holds a major share in the use of such alternative inputs.

The production data of the global DRI industry is furnished in Table I

It may be observed from the above table that between 2000 and 2004, the global production of DRI has increased at an average yearly rate of 6.53 percent.

India was the third highest producer of DRI in the world in 2000, second highest producer in 2002 and the highest producer in 2001, 2003 and 2004. In 2005 also India was the highest producer.

Region wise, in 2004, Asia was the highest producer of DRI in the world.

Presently, DRI is very much on strong ground. According to experts its future growth in the global arena is guaranteed, driven by:

- ❖ Growth of EAF steelmaking
- ❖ Insufficient supply of prime scrap (particularly in terms of quality)

It has been estimated that the world production of DRI may reach a level of 60 Mtpy by 2010.

5. Composition of Internationally Traded DRI:

The usual chemical composition of DRI traded in the international market is as follows:

Parameter	%
Total Fe	94-96
Metallic Fe	86.90
Degree of Metallisation	92-95 ± 1.2
Carbon	1.0-1.5 ± 0.3
Sulphur	0.005-0.01
Phosphorus	0.2-0.9
Silica	1.0 to 2.0

For maximum yield, the metallic iron content should be at the highest possible level with sulphur and phosphorus as low as possible. Gangue content should preferably be up to 2 percent and Silicon less than 3 percent to ensure low slag volume, less power consumption and for obtaining higher productivity.

Size should be minimum with less than 3mm fraction to prevent losses during charging and handling operations. The density should be high to facilitate faster melting to help energy conservation.

Table 1 : Global Production of DRI : 2000-2004 (Million Tonnes)

Country	2000	2001	2002	2003	2004
F.R. Germany	0.5	0.2	0.5	0.6	0.6
Sweden	0.1	0.1	0.1	0.1	0.1
EU (15)	0.6	0.3	0.7	0.7	0.7
Russia	1.9	2.5	2.9	2.9	3.1
CIS	1.9	2.5	2.9	2.9	3.1
Canada	1.1	0.0	0.2	0.5	1.1
Mexico	5.6	3.7	4.7	5.5	6.3
United States	1.6	0.1	0.5	0.2	0.2
NAFTA	8.3	3.8	5.4	6.2	7.6
Agentina	1.4	1.3	1.5	1.7	1.9
Brazil	0.4	0.3	0.4	0.4	0.4
Peru	0.1	0.1	0.0	0.1	0.1
Trinidal & Tobago	1.5	2.0	2.3	2.2	2.2
Venezuela	6.4	5.5	6.8	6.6	7.8
Central & South America	9.8	9.2	11.0	11.0	12.3
Egypt	2.1	2.4	2.5	2.9	3.0
Libya	1.5	1.1	1.2	1.3	1.6
Nigeria	0.0	0.0	0.0	0.0	0.0
South Africa	1.5	1.6	1.7	1.5	1.6
Africa	5.1	5.0	5.4	5.7	6.2
Iran	4.5	5.0	5.3	5.0	6.4
Qatar	0.6	0.7	0.8	0.8	0.8
Saudi Arabia	3.1	2.9	3.3	3.3	3.4
Middle East	8.2	8.6	9.3	9.1	10.7
China	0.1	0.1	0.2	0.3	0.4
India	5.5	5.7	5.7	7.1	9.1
Indonesia	1.7	1.5	1.4	1.2	1.5
Malaysia	1.2	1.0	1.1	1.6	1.7
Myanamar	0.0	0.0	0.0	0.0	0.0
Asia	8.6	8.4	8.5	10.2	12.7
Australia	0.3	1.4	1.0	2.0	0.7
Oceania	0.3	1.4	1.0	2.0	0.7
WORLD	42.9	39.2	44.2	47.8	54.1

(Data Source : World Steel in Figures, 2005. IISI Brussles)

N.B.: Totals may not agree in some cases due to "rounding off."

6. Raw Materials:

The major raw materials required for production of sponge iron are iron oxides in the form of lump iron ore/pellets, non-coking coal and fluxes (limestone and dolomite). Some precaution is necessary in selecting the iron oxide specially its phosphorus content and its reliability for easy reduction. Use of high purity pellets with low Phosphorus at an economic price, helps in the cost effective production of sponge iron.

7. Advantages of Using DRI in EAF Process:

(a) General

The addition of DRI to scrap in the feedstock in an EAF process brings about a remarkable reduction in the impurities like Sulphur and phosphorus. The dilution of the change mix decreases the refining requirements resulting in simplification of the metallurgical operation, inside the furnace and increases the furnace productivity. Very often, it has been found that sufficient dilution has helped to complete most of the refining in the furnace itself during the melting operation, thus further increasing productivity.

b) Continuous Feeding of DRI

Continuous feeding of DRI results in achieving higher power level than 100 percent scrap charge with similar settings in the EAF. Due to the heterogeneous nature of scrap and the continuously varying arc length 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 increased saving up to 15 KWh per tonne in power consumption with the use of UHP transformers.

c) Hot Charging of DRI

Hot charging of DRI is an effective means of lowering the cost per tonne of liquid steel produced because of the reduction in power and electrode consumption. In addition to reduction in power consumption and savings thereof, hot charging of DRI increases the EAF productivity for a meltshop designed to charge cold DRI.

In India, the hot DRI technology is an innovation of Essar Steel Ltd. and saves about 120 kWh of energy per tonne of H DRI consumed by the EAF shop with the utilization of 650^{0}C heat contained in the iron.

Other Benefits

(i) Lower Electrode Consumption

The use of DRI vis-à-vis scrap helps in lower electrode consumption due to the following reasons.

- Scrap collapse results in increased breakages which is much less incase of DRI charge.
- The productivity of the furnace is higher in case of DRI user. Due to high CO content in the furnace, electrode oxidation is decreased.

(ii) Lower Oxygen Consumption

- The need for oxygen in scrap cutting is not required.
- The oxygen input in DRI is associated with unreduced oxides.
- The unreduced iron oxide in DRI is sufficient to provide the slag requirements for iron oxide.

(iii) Reduction in Lime Consumption

By using lime or dolomite bonded pellets for DRI production, the requirements for lime addition as a fluxing material can be reduced to a large extent.

(iv) Lower Refractory Consumption

Maintaining a deep foamy slag during continuous feeding of DRI can minimize arc radiation and the foamy slag also increases the thermal efficiency as compared to all scrap charge.

By balancing the feeding rate with power input and raising the bath temperature towards the end of melting stage with decreased feeding rates, the refractory consumption is reduced.

8. Characteristics of Some Major DRI Processes

Some of the characteristics of Major DRI Process showing feedstock and reductant used, reduction system and operating conditions are shown in Table 2

Table 2: Characteristics of Direct Reduction Process

Process	Feed Stock	Reductant	Reactor Type	Temperature	Pressure
Finmet	Fines	Gas	Fluidised Bed	Medium	High
HYL	Pellet/Lump	Gas	Shaft Furnace	Medium	Low
Midrex	Pellet/Lump	Gas	Shaft Furnace	Medium	Low
Davy DRC	Pellet/Lump	Carbon	Kiln	High	Atmos
SL/RN	Pellet/Lump	Carbon	Kiln	High	Atmos

(Source: Article by Dr. Amit Chatterjee, Tata Steel)

The Indian Scenario:

Sponge Iron India Ltd. (SIIL) was the first sponge iron plant in the country which was set up at Paloncha in Andhra Pradesh in 1990 with an initial capacity of 0.03 Mtpy. Since coal was adequately available in India, production of coal-based sponge iron plants was considered as a feasible option. The growth of the DRI industry in the country till the mid-eighties of the last country was, however, constrained by the restrictive licensing policy of the Government. It was only after delicensing in 1985, that the industry expanded rapidly.

Between 1984 and 1988, only three sponge iron plants were set up. There were Orissa Sponge Iron Ltd. With an initial capacity if 0.1 Mtpy, Ipitata Sponge Ltd. (now Tata Sponge Ltd.) with an initial capacity of 0.09 Mtpy and Sunflag Iron & Steel Ltd. with an initial capacity of 0.15 Mtpy.

In the late eighties of the last century, the Indian producers become enthusiastic in setting up gas-based sponge iron plants due to the discovery of large scale reserves of natural gas in the country. The first gas-based sponge iron plant was started up at Hazira in Guajarat in 1990 by Essar Steel Ltd.

Among the three gas-based sponge iron producers, Essar Steel setup the world's largest hot-briquelted iron (HBI) plant with Midrex technology with an initial capacity of 1.7 Mtpy which has been expanded to 2.4 Mtpy and further to 3.6 Mtpy in 2005. Ispat Industries was the first in the world t set up a Midrex Megamod unit, the world's first largest single module sponge iron plant at Dolvi in Maharashtra which started commercial operation in January 1995. Its present capacity is 2.4 Mtpy. Grasim Industries set up its Vikram Ispat Sponge Iron plant on the western coast at Salav in Maharashtra with a capacity of 0.9 Mtpy. It was globally the first plant to install the HYL III technology from HYLSA of Mexico which began operation in 1993. According to HYL it was the first Zero kWh DRI plant.

9. Number of Sponge Iron Plants Units:

According to SIMA sources, there were about 180 sponge iron plants/units in India at the end of 2005. Other 170 units are in various stages of planning, construction and commissioning. Except the big three gas-based projects of Essar Steel, Ispat Industries and Vikram Ispat, almost all are coal-based plant/unit. Jindal Steel & Power Ltd. (JSPL) coal-based plant at Raigarh in the Chattisgarh state is the world's biggest coal-based sponge iron plant with a capacity of 1.3 Mtpy more than 55 percent of these coal-based units are mini sponge iron producers having a capacity up to 50,000 tpy. According to Sponge Iron Manufacturers Association (SIMA), the total installed capacity of the gas based sponge iron plant at present is 6.1 Mtpy and that of the coal-based plant/units is about 9.53 Mtpy including 2.5 Mtpy capacity of non-member units.

10. Production of DRI/Sponge Iron in India:

The total production of DRI in India may exceed 11 Mt mark in 2005-06. It is apparent from the above table that the total productions of the gas-based plants were higher than the coal-based plants/units between 1995-96 and 2002-03. In the following two years, the coal-based plants have outstripped the output of the gas-based plants.

The year 1998-99 was a bad year for the Indian Sponge Iron Industry as the output of gas-based and coal-based recorded negative growths. Between 1995-96 and 2004-05, the average yearly growth of production of gas-based plants has been 6.31 per cent while that of the coal-based plants rose by 35.9 per cent.

b) Raw Materials:

The main raw materials required for a coal-based plant are iron ore, suitable coal, dolomite and power.

Production data of DRI/Sponge Iron in India is shown in Table : 3

Table 3: Production of DRI/Sponge Iron in India : 1995-96 to 2004-05 (Mt)

Year	Gas Based		Coal Based		Total	
	Production	Growth (%)	Production	Growth (%)	Production	Growth (%)
1995-96	2.96	---	1.28	---	4.24	---
1996-97	3.33	12.5	1.68	31.3	5.01	18.2
1997-98	3.64	9.3	1.70	1.2	5.34	6.6
1998-99	3.45	-5.2	1.73	1.8	5.18	-3.0
1999-00	3.46	0.3	1.88	8.7	5.34	3.1
2000-01	3.46	0.0	2.02	7.4	5.48	2.6
2001-02	3.17	-8.4	2.49	23.3	5.66	3.3
2002-03	3.63	14.5	3.28	31.7	6.91	22.1
2003-04	3.98	9.6	4.11	25.3	8.09	17.1
2004-05	4.64	16.6	5.42	31.9	10.06	24.3

Data Source: SIMA

11. Coal-Based Projects

India is the highest producer of coal-based sponge iron in the world. As mentioned earlier JSPL has the highest capacity among the coal-based plants in the world.

Some of the major innovations in the coal-based technology in India are mentioned below:

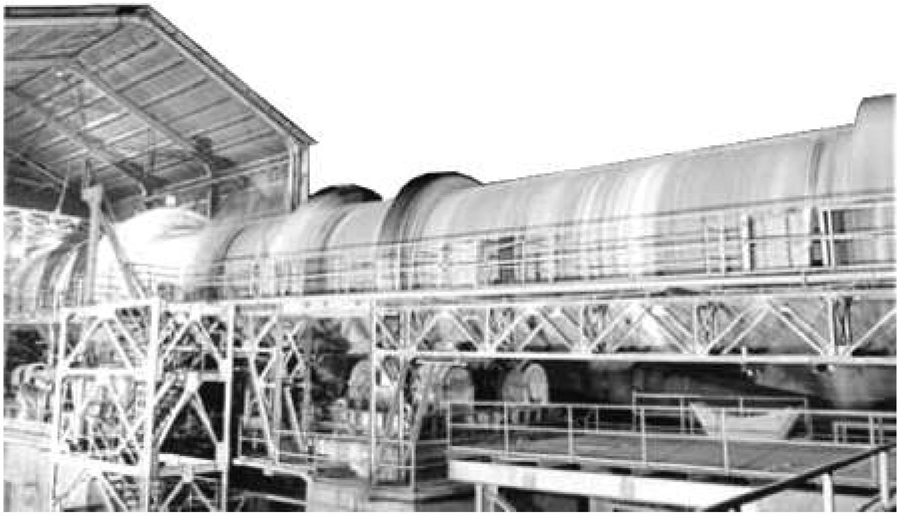
a) Capital Requirement Reduced:

Upto 1998, nearly 80 percent of the equipment was imported. But at present, for a 1,20,000 tpy module, 100 per cent indigenous equipment is available. For a 150,000 tpy module only kiln tyres and support rollers are being imported. After 1998, capital expenses related cost has thus been reduced from Rs. 75 crore to Rs. 40 crore for a 120,000 tpy module while the same for a 150,000 module has comedown to from 110 crore to 60 crore.

i) <u>Iron Ore :</u> Iron Ore with a Fe-content of 62-66 percent (hematite) is usually used. Earlier, the ore size was kept at 5.20mm and was washed in a scrubber. But at present 5-18mm size ore are used as a feed stock for large kilns without scrubbing / washing. This has led to a reduction of DRI consumption from 1.6 Mt to 1.5 Mt per tone of hot metal produced.

ii) <u>Coal :</u> Due to the non-availability of B-grade coal from Coal India, C and D Grades coals are being presently used. The industry has successfully adopted measurers to utilize these grades through better process control and the cost has been reduced by 20-30 percent as compared to B Grade used earlier.

iii) <u>Dolomite :</u> Earlier dolomite of 1 to 4mm size was being used. At present the use of 4 to 8 size has reduced the consumption by about 50 percent by



minimizing a significant loss of dolomite fines through waste gases.

iv) __Power :__ Previously, the power consumption per tonne of sponge iron was about 110-130 units. But with the advent of dry gas cleaning system through electro-static precipitator, programmable logic operator drivers and computer control, the power consumption has been reduced to 80-90 units per tonne of sponge iron produced.

All the above innovations has resulted in a better capacity utilization from 85 to 90 per cent to 100 percent or more in well established plants.

Most of the smaller sponge iron units are yet to modernise and adopt technology upgration and do not follow the prescribed pollution control norms. Experts opine that unless these units adopt remedial measurers many of them will have to face closure in future.

12. Coal Requirement:

The coal required for producing sponge iron in coal-based plants should have a metallurgical property known as "reactivity" for it to be suitable for sponge iron production. Coals with high reactivity facilitates the carbon in reacting with the Oxygen in the iron ore to form Carbon Monoxide (CO), whereas coals with low reactivity will not react sufficiently with iron ore and will tend to remain largely inert in the direct reduction process and will exit the kiln as high carbon char/waste product and the resulting sponge iron would be of low metallization and unsuitable for use as a charge material in an electric furnace.

Therefore, for a rotary kiln based coal-based sponge iron process to be successful, it is absolutely necessary to use non-coking coals having high reactivity characteristics and high ash fusion temperatures. Unfortunately, most of the Indian non-coking coal do not satisfy the above criteria, and are, therefore, not suitable for sponge iron production. Such non-coking coals can be used for heating purposes in power plants etc. where there is no need for "metallurgical reduction".

In the sponge iron manufacturing process, the coal acts more as a reductant and, therefore, acts as a feed stock than as a mere fuel providing heat to the process.

13. Replacing Met Coke:

India producers have witnessed an acute shortage of met coke for the last few years. This has driven the exports to think about a different process route without using met coke. The basic feed material in this route is sponge iron which is produced using iron ore and reactive non-coking coal. This has triggered the growth of sponge iron industry in India which has led to the setting up of numerous mini/medium/mega sponge iron plants/units in the states where in or ore and suitable non-coking coals are abundantly available.

14. Charging of Sponge Iron in Blast Furnaces:

Dr. K.K. Prasad of RDCIS, Steel Authority of India Ltd. has made the following valuable observations on the issue of charging sponge iron in Blast Furnaces.

- ❖ Technically and technologically, sponge iron has been found to be a suitable material for charging in blast furnaces.
- ❖ Some of the negative technological aspects of charging may be overcome if sponge iron producers plan dedicated production campaigns for blast furnace use. Producers may further benefit by suitably designing dedicated units for making blast furnace sponge iron.
- ❖ Use of sponge iron in BFs may not pick up very strongly at present, but, in the medium term, the economics is expected to change in favour of charging sponge iron in BFs. The iron units in blast furnace burden would then become an optimum mix of lump iron ore, sinter and sponge iron.

- Bfs need higher size of sponge iron and can compromise on metallization. An interesting possibility exists where lump ore feed for BFs can be treated in sponge iron rotary kiln before charging in blast furnaces. Undersize may go into steelmaking.
- India is going to need all the iron which Blast Furnaces and the sponge iron Industry can produce, either together or with the help of each other.

additional modern iron ore mining and beneficiation capacity of 200Mt. The size of the investments would be about Rs. 20,000 crore, Long-term export of iron ore will be limited to a maximum of five years contracts. The NSP has also visualized a production capacity growth of Indian sponge iron industry upto 38 Mtpy in 2019-20. It also states that the sponge iron and steel industry would get first priority in the allveation of higher grades of non-coking coal below 12 percent ash content.

15. Projections of Installed Capacity & Production of Sponge Iron By SIMA :

The projections of Sponge Iron Manufacturer's Association (SIMA) about installed capacity and production of the Indian Sponge Iron Industry are furnished in Table : 4.

Table 4: SIMA Projection of Installed Capacity and Production By Indian Sponge Iron Industry upto 2009-10 (Mt)

Year	Installed Capacity			Production		
	GAS-BASED	COAL-BASED	TOTAL	GAS-BASED	COAL-BASED	TOTAL
2004-05	6.1	6.0	12.1	4.64	5.42	10.00
2005-06	6.1	8.5	14.6	5.70	6.50	12.20
2006-07	7.1	11.0	18.1	7.00	8.50	15.50
2007-08	7.1	13.0	20.1	7.00	10.00	17.00
2008-09	7.1	15.0	22.1	7.00	11.00	18.00
2009-10	7.1	18.0	25.1	7.00	14.00	21.00

(Source: SIMA)

16. NSP Formulation:

The National Steel Policy announced by the Government in November, 2005 has visualized a steel production of 110 Mtpy and a consumption of 90 Mtpy in 2019-20. According to the estimates of the NSP, the requirements of iron ore, coking coal and non-coking coal in 2019-20 would be 190 Mt, 70 Mt and 26 Mt as against 54 Mt, 27 Mt and 13 Mt in 2004-05 respectively.

The Government would encourage investments in creation of an

17. Conclusion:

In recent years the Indian sponge iron industry has shown high growth in production, technology upgradation except by some of the smaller producers. The prescriptions of the National Steel Policy regarding massive pelletisation and supply of high grade coal to sponge iron industry would largely help the producers.

Stupendous growth in infrastructure is required to meet the targets laid down by the National Steel Policy. Government has a major role to encourage and monitor timely completion of the infrastructure development projects. The private sector has also to play a positive role in this regard.

It all the efforts of the Government and the producers in the development of the industry succeed, the Indian Sponge Iron Industry would remain in the top berth in the global arena in future.

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