Steelmaking Process Route - Options for India

- N. M. Rao, Consultant (I&S)

PART-I

Ministry of steel in its draft National Steel Policy, 2012, has projected that India's crude steel capacity will reach 300 MT by 2025 and that the finished steel consumption will be 233 MT (considering 8% GDP growth, 1.11 implicit GDP elasticity and FY 2011-12 as the base). The consumption has been projected at 202 MT at 7% GDP growth. The National Council of Applied Economic Research (NCAER) in its report 'The Indian Steel Industry: Key Reforms for a Brighter Future', submitted in September, 2015, has projected the aspirational goal for peak finished steel consumption in India to be 600 MT in 2050 considering 6% growth in India's per capita income between 2013 and 2050. Crude steel capacity required for this has been projected as 720 MT. Per capita finished steel consumption is projected to reach 400 Kg in 2050 (58.6 Kg in 2014). Though India was the third largest producer of crude steel in 2015, actual production was only 89.6 MT. Capacity as on March, 2015 was about 110 MT. Hence, India has to add a capacity of about 200 MT in 10 years and 600 MT in 35 years. This paper looks at the probable process route (s) for steel making for achieving the projected capacity level in 2025.

Present Position

The steel industry in India is more than century old, with the Jamshedpur plant of Tata Steel being in operation since 1907. Subsequently, IISCO, Burnpur came into being. These two plants operated with the open hearth process for a long time. By fifties, oxygen steelmaking (BOF) was getting popular in advanced countries. When the Government owned steel plants were set up in late fifties, LD or BOF process was chosen for the Rourkela steel plant. In other two plants at Bhilai and Durgapur, open hearth process was adopted. Since oxygen steel making proved to be advantageous in respect of productivity and energy consumption, Tata Steel and public sector plants gradually switched over to BOF process. Now, only Bhilai makes some steel through twin hearth furnace. Even this will be closed down after the units under expansion are commissioned. At Burnpur, a new and modern plant based on BOF is getting stabilised. All these plants use blast furnace for iron making. All plants have incorporated latest technological features. Private sector entered steel sector in a big way in nineteen nineties. Many of these players chose electric arc furnace (EAF) for steel making (Jindal South West however makes steel through BOF at Torangallu). Earlier, EAF was used by mini plants mainly to make special steels. New generation of steel plants introduced alternate processes for iron making. Essar steel and Ispat Industries (now JSW) used Midrex process for producing DRI/HBI using natural gas as fuel; while JSPL adopted SL/RN process for making coal based DRI. JSW was the first company to adopt Corex process of smelting reduction technology. Subsequently, this process was adopted by Essar steel also. However, all these companies set up blast furnaces also to use liquid hot metal as a part of the metallic for EAF. This was done mainly with a view to reduce power consumption in EAFs. Meanwhile, several medium and small players set up induction furnaces all across the Country and today about one-third of crude steel is made through induction furnaces. They operate with locally available scrap, coal based DRI procured from small coal based sponge iron plants and some pig iron. Process route adopted by both major companies and some medium size companies, is shown in table-1 (source: Web site of Ministry of steel and respective companies).

Some other companies like FACOR, ISI Bars, ISMT, Jailaxmi steel, Kalyani Carpenter, L&T Special steel, MUSCO, Marmagoa, Mid India power & steel, Mittal corporation, Modern Steel, Mukand, Remi Metals, RL Steel & energy, Star wire (India), SAIL (ASP & Salem), Shah Alloys, Upper India Steel, Vardhaman Special steel, Viraj profiles etc. use EAF process to make various grades of steel. They do not have iron making facilities. They are mostly scrap based; but use some

Company	Steel Making		Iron Making		
	Process	Capacity, MT	BF	DRI	SR
SAIL- ISPs & VISP	BOF	20.7	Yes	-	-
Tata Steel	BOF	15.7	Yes	-	-
RINL	BOF	7.3	Yes	-	-
JSWL, Toranagallu	BOF	10.0	Yes	-	Corex
	EAF	1.5	-	Midrex (Corex gas)	Corex
JSWL, Dolvi	EAF	4.0	Yes	Midrex (NG)	-
JSWL, Salem	EOF	1.0	Yes	-	-
Essar Steel	EAF	10.0	Yes	Midrex (NG)	Corex
JSPL, Raigarh	EAF	4.0	Yes	SL/RN	-
JSPL, Anugul	EAF	6.5	-	Coal syn gas	-
Bhushan Steel	EAF/IF	5.2	Yes	SL/RN & Syn gas	-
BPSL	EAF	2.5	Yes	SL/RN	-
NMDC	BOF	6.0	Yes	-	-
Electro Steel	BOF	1.7	Yes	-	-
Monnet Ispat	EAF	1.5	Yes	SL/RN	-
Jindal Stainless	EAF	1.8	-	-	-
BMM Ispat	EAF	1.0	-	SL/RN	-
Usha Martin	EAF	0.7	Yes	SL/RN	-
SBQ Steels	BOF	0.5	Yes	-	-
Visa Steel	EAF	0.3	Yes	SL/RN	-
Sunflag I&S	EAF	0.36	Yes	SL/RN	-
Kalyani Steels	EOF	0.4	Yes	-	-
Jai Balaji	EAF	0.3	Yes	SL/RN	-
Jayaswal NECO	EOF	0.3	Yes	SL/RN	-
Gerdau	BOF	0.3	Yes	-	-
Adhunik	EAF	0.3	Yes	SL/RN	-
Aarti Steel	EAF	0.3	-	SL/RN	-

purchased DRI/pig iron. The combined capacity of these companies is about 5.0 million tonnes. Jindal stainless also is in this category, but has been included in the table, since it is a major producer with over 1 MTPA capacity.

Total BOF capacity as per above table is 62.2 MT, while that of EAF/EOF is 48.5 MT. All of this capacity, particularly in respect of big companies, is not commissioned fully. However, except for some delays, all of this is expected to be commissioned in the next couple of years. Besides, induction furnaces across the country together have a capacity of about 35 MT. Except for JSPL Anugul, BMM Ispat and Aarti steel, all EAF based plants have set up blast furnaces and all of them except Kalyani and Gerdau have DRI plants. Uttam Galva, Nagpur have announced 1.5 MT plant based on Finex-EAF, while JSW proposes to set up 3 MT plant at Satarda in Maharashtra, based on Corex/DRI-EAF. Kalyani steel proposes to have 1.0 MT plant at the present site based on BF-BOF. All of this will add up to a total capacity of 151 MT; of which BOF is 42%, EAF/EOF is 35% and IF 23%. There have been several other announcements particularly ultra-mega steel plants, but their configuration is not known. Since all the capacity shown in the table is not fully commissioned and capacity utilisation was low, actual ratio in 2014-15 was 44% BOF, 23% EAF and 33% IF. Iron making capacity is estimated at 65 MT Blast furnace (excluding MBFs who cater to the needs of foundry industry or have their own casting units), 48.6 MT DRI (of which gas based is 12.6 MT) and 3.5 MT Corex. The ratio works out to 56%, 41% and 3% respectively. However, due to low capacity utilisation of sponge iron industry, actual ratio in 2014-15 was 73% blast furnace, 23% DRI and 4% Corex. EAF based units are using blast furnace hot metal up to 50% (in some cases 70 to 90%) to reduce power consumption and the overall cost of production (actual ratios are based on JPC reports).

Factors for Selecting Process Route and the Indian Position

There is now a growing concern regarding greenhouse gas emissions. Hence, steel should be made without using carbon if possible, or by using as less carbon as possible. Following factors assume significance in selecting the processes.

- Processes which emit low greenhouse gas emissions
- Processes which can use higher amounts of ferrous scrap
- Processes which give economies of scale
- Processes which give higher productivity
- Processes which use less quantity of coal
- Processes which can use cheaper raw materials

Energy intensity and carbon dioxide emissions under various process routes are shown in table-2

(source: www.spongeironindia.in/midrex.pdf)

TABLE-2

Process	Metallic Ratio	Energy Intensity G Cal/tls	Carbon Dioxide Emission T/tls
BF-BOF	90% Hot Metal + 10% scrap	4.5-5.0	1.8-2.3
DRI-EAF	80% CDRI + 20% Scrap	4.2-4.5	1.1-1.3
DRI-EAF	80% HDRI + 20% Scrap	~4.0	1.0-1.2
DRI-EAF	30% HBI + 70% Scrap	2.8-3.0	0.8-0.9
DRI-EAF	30% HDRI + 70% Scrap	2.5-2.8	0.7-0.8
BF-EAF	30% Hot metal + 70% Scrap	2.4-2.7	1.2-1.3
EAF	100% Scrap	1.5-1.6	0.4-0.5

Specific energy consumption and CO2 emissions are highest in BF-BOF route. EAF process using 100% scrap is the best option in this regard. EAF process with scrap and DRI (gas based) mix lies between these two extremes. In India almost 60% of crude steel is made through electric process.

However, energy consumption and CO2 emissions in Indian steel industry are considerably higher than the world averages. This is because, in spite of increase in electric steel making, use of blast furnace hot metal has not come down as can be seen from table-3 (source: JPC; all quantities are in MT). This is partly because of lower production of DRI and partly because of the need to reduce power consumption, since power tariffs in India are high. Further, blast furnace coke rates in India are high.

In USA and Europe, production of hot metal has declined with the increase in the share of electric process. The decline has been nearly 20% between 2005 and 2014. Number of blast furnaces has also come down. This has not happened in India because Blast furnace continues to be the preferred process for iron making, both for BOF and EAF steel making in spite of low productivity (compared to international achievement), high fuel consumption and high greenhouse gas emissions.

It can also be observed from the above table that scrap usage has been about 38 MT in 2014-15. Sources of this quantity are not fully known. Internal generation in steel industry can be considered as 10 MT (10% of metallic). Collection, processing and recovery of scrap from industrial and other sectors of the economy is not properly organised in India. There is no published figure regarding scrap availability from these sources. As per one estimate, this is about 10 MT.

Hence, including import, only about 25 MT was available. It is therefore clear that small players, particularly in induction furnace segment, have used locally available dirty scrap. This affects both productivity and quality. If India has to achieve 270 MT crude steel production (90% of capacity), scrap requirement is 91 MT (at 30% of metallic) in 2025, assuming that crude steel to metallic ratio will be 88%. This would require procuring at least 60 MT from outside sources (including imports). Steel is 100% recyclable and every tonne of scrap used saves 1.4 T of iron ore, 0.74 T of coal and 0.12 T of limestone (source: www.worldsteel.org). Currently, scrap usage in India is limited both due to availability and quality.

Blast furnace process requires superior quality raw materials. The process is dependent on coking coal which is available in only a few countries (India does not have reserves of good quality coking coal). Blast furnace route is capital intensive since it requires coke ovens and sinter plant. The process also requires more quantity of water. It will be difficult to lower the production, if necessary, to match the market needs in case of CO-SP-BF because of the continuous nature of operations and the safety of the equipment. BOF process has limitation in using scrap. Normally, it is 10% and generally it is not more than 20%. In this respect, EAF process has more flexibility.

In DRI-EAF route, pellets made from inferior quality iron ore can be used (after beneficiation) for DRI production. DRI can be made from non-coking coal or natural gas. India is not having adequate resources of natural gas. However, operation with the alternative of Syn gas through coal gasification has now been established in JSPL, Anugul. This process can use high ash Indian coals. It was reported that DRI produced has a metallisation of 93% and carbon 1.8% ('Iron & Steel Review', October, 2015). The discharge temperature was 700°C. India is also successfully using smelting reduction process of Corex which gives liquid hot metal (JSW, Toranagallu and Essar, Hazira). Use of Corex off gases for DRI production has also been successfully commercialised in JSW, Toranagallu. It has been reported that DRI produced has a metallisation of 92% minimum and carbon 1.3% ('Iron & Steel Review', January, 2016). A charge mix of about 50% HDRI, 40% hot metal (Corex) and 10% scrap was used in EAF. Tap to tap time obtained was 50 minutes. Power and electrode consumption were low.

In both these DRI technologies, CO2 removal system has been incorporated. Another smelting reduction process, Finex, which is being used in South Korea, is also proposed to be used in India. This also produces liquid metal and off gases. Uttam Galva Metallic proposes to use this process as a part of its 1.5 MT steel plant based on EAF. The ITmk3 process, which produces iron rich nuggets, is being actively considered by SAIL for adoption in Alloy Steel Plant, Durgapur, which is a special steels plant based on EAF.

TABLE-3

YEAR	CRUDE STEEL PRODUCTION	HOT METAL PRODUCTION	PIG IRON PRODUCTION	HOT METAL FOR PI	HOT METAL FOR STEEL	DRI PRODUCTION
2006-07	50.82	34.67	4.96	5.39	29.28	16.28
2007-08	53.86	36.76	5.31	5.77	30.99	19.99
2008-09	58.44	37.05	6.21	6.75	30.30	21.33
2009-10	65.84	41.52	5.95	6.61	34.91	22.99
2010-11	70.67	42.93	5.78	6.28	36.65	23.25
2011-12	74.29	44.70	5.78	6.28	38.42	20.56
2012-13	78.42	48.69	7.28	7.91	40.78	18.67
2013-14	81.69	52.46	7.68	8.35	44.11	18.11
2014-15	88.25	56.32	9.70	10.54	45.78	17.46

TABLE-3 (CONTINUED)

YEAR	METALLIC FOR CS	PROPORTION OF METALLIC, %			IMPORT OF SCRAP	ELECTRIC PROCESS, %
		HOT METAL	DRI	SCRAP		
2006-07	58.41	50.13	27.87	22.00	2.18	50
2007-08	61.91	50.16	32.29	17.65	2.56	52
2008-09	67.17	45.11	31.75	23.14	3.16	53
2009-10	75.68	46.13	30.38	23.49	5.34	55
2010-11	81.23	45.12	28.62	26.26	4.51	56
2011-12	85.39	45.04	24.08	30.88	6.82	58
2012-13	90.14	45.24	20.71	34.05	8.00	58
2013-14	93.90	46.98	19.29	33.73	4.66	57
2014-15	101.44	45.13	17.21	37.66	4.75	56

EAF process itself has seen several developments like rapid melting technology, DC-EAF, water cooled panels, oxy-fuel burners, bottom stirring by inert gas, eccentric bottom tapping, continuous charging of hot DRI, foamy slag practice, scrap pre-heating, extensive process automation etc. These have helped in achieving high productivity and economies of scale in DRI-EAF process route comparable to BF-BOF route. Essar steel, Hazira has set up 150 T DC Conarc furnaces (low electrode consumption), JSW Dolvi 200 T twin shell Conarc furnaces, JSPL Anugul, 250 T EAFs and Bhushan Steel 180 T twin shell Conarc furnaces. These furnaces have great flexibility with regard to charge mix. They can operate with 100% scrap or any mix of scrap, DRI and hot metal. These furnaces are also capable of making all sophisticated grades of steel. JSPL at Raigarh, Bhushan steel and several others as shown in table-1, produce and use coal based DRI in EAFs along with hot metal and scrap. Compared to gas based DRI, coal based DRI has lower metallisation and lower carbon content. Hence, EAFs operating with coal based DRI get lower yield and higher power consumption compared to those operating with gas based DRI. Besides, Indian coals have high ash content and hence coal consumption and generation of char and accretions are higher. It should also be noted that natural gas emits only about one-half of CO2 per unit of energy as compared to coal.