Analysis of Emerging Iron Making Processes – Indian Context

Dr. T. Venugopalan, Mr. Ramana

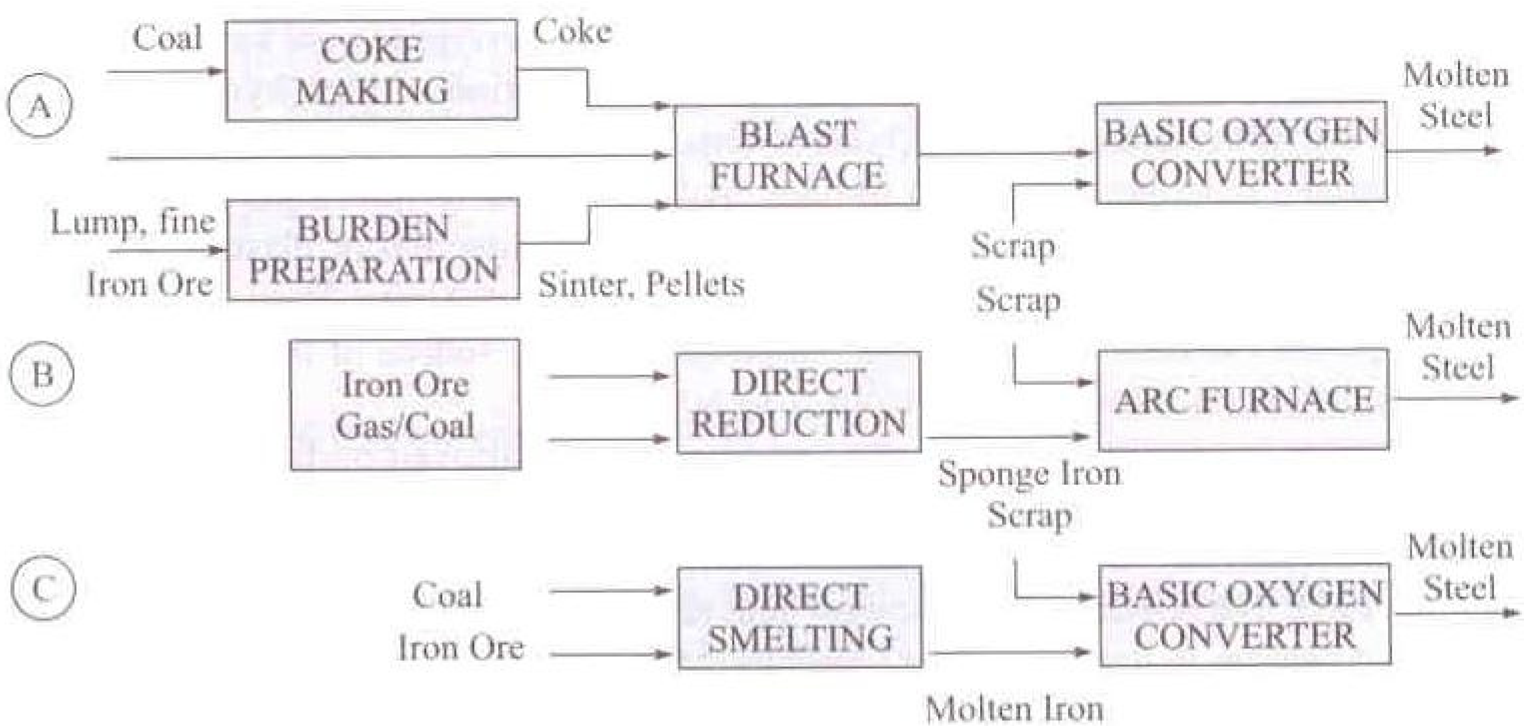
Chief Technology Officer

Tata Steel

Raw Materials for Iron Making

- **Iron Ore : Mainly Hematite and Magnetite. Currently good quality iron ores (>65%Fe) available in states of Orissa, Jharkhand and Chattisgarh. Quality expected to deteriorate in the next decade due to changes in formation.**
- **Coal: Coking coal situation not favourable in India. Reserves have high ash (around 30%) and low rank.**
- **Natural gas: Available in Western India and KG Basin**

Basic Routes to Produce Molten Steel

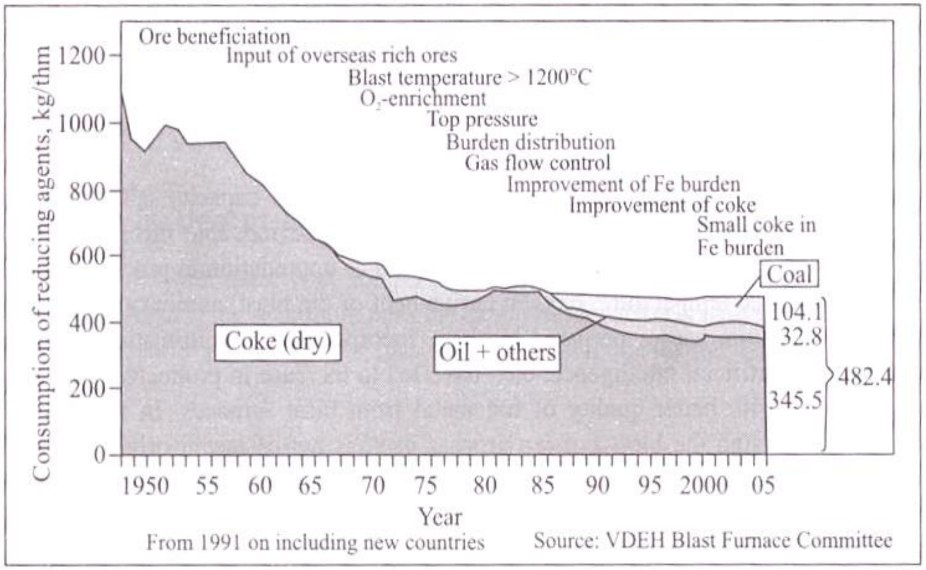


Salient Features of Steel Making Routes

Process route	*Development potential*	*Scale of operation (Mtpa)*	*Material preparation*	*Process steps*	*Ecological assessment*
Blast furnace (BF)/Basic oxygen furnace (BOF)	Proven process. Many improvements made: high coal injection, high top pressure/ blast temperature, blast enrichment, etc.	3–6	Iron ore sizing/ blending, sinter/ pellet plant, coke ovens, etc.	Sinter/pellets, coke, BF/ BOF refining using oxygen.	Rigorous cleaning required for solid/liquid/ gaseous emissions at all stages, particularly coke ovens.
Electric arc furnace (EAF)	Proven process. Many improvements are made: DC arc, twin shell, UHP furnaces, water cooled panels, external pre-heating of scrap, etc.	0.5–2	Scrap segregation and preparation. Number of steps involved is the minimum.	Melting of scrap in EAF using electricity and oxygen.	Hardly any emissions. Gas emitted by EAF cleaned in gas cleaning plant.
Gas-based direct reduction to produce sponge iron/ direct reduced iron (DRI)	Already several processes have been developed and others are in the pipeline.	1–1.8	Essentially dependent on pellets, along with some lump ore. Processes to use fines have been recently developed.	DRI has to be melted in EAF along with scrap (sometimes also hot metal from BF/MBF)	Clean technology.
Coal-based direct reduction	Rotary kiln technology fully developed. Rotary hearth processes being developed.	0.25–0.5	Uses lump ore and special type of coal. Can use pellets.	DRI + EAF	Problems can arise with disposal of solid wastes.
Smelting reduction (SR) to produce hot metal (like BF)	Some processes like Corex, Finex already proven. Others like Hismelt are in advanced stage of development.	0.3–0.8	Corex uses lump ore and pellets. Finex uses briquettes made from fine ore and fine coal. Hismelt uses coal/iron ore fines directly.	No sinter plant, no coke ovens. Hot metal from SR charged to BOF/EAF.	Clean technology at both ironmaking and steelmaking stages.

Existing Blast Furnace Technology

- Several radical transformations to improve BF efficiency and productivity
- Continuous efforts to reduce coke consumption, and slag generation
- High level of automation and use of process models to achieve hot metal quality and consistent furnace performance



Progress in Blast Furnace Technology in last 50 years

- Iron ore beneficiation and use of rich ores
- Use of iron ore pellets
- Oil injection
- Higher blast temperature (1200 deg C, Oxygen enrichment)
- Bell less top, High Top Pressure
- Burden Distribution, Gas flow control

Progress in Blast Furnace Technology in last 50 years

- Improvement in Fe burden properties
- Improvement in coke properties
- Pulverized coal injection
- Copper staves for BF cooling
- Campaign life beyond 15 years
- Nut coke charge

Challenges for Blast furnace Iron making

- High ‘P’ and high alumina in iron ore
- Non availability of hard lump ore
- Limited resources of good quality coking coal (high ash and low rank)
- High capital cost

Development in BF – BOF technology to meet the challenges

- Hot metal pretreatment – De-Si, DeP and DeS of hot metal
- Development of external DeS and ORP
- Stamp charge batteries for the production of good quality coke
- Production of Pellets from friable / fine ore deposits to replace Iron ore lump
- Non recovery coke ovens , replacing ageing coke oven batteries to avoid pollution

Role of Alternative Iron making

- Improvement in the productivity of the existing Iron and Steel units
- Increase in operational flexibility in terms of raw materials, minimum capacity for efficient operation
- Opportunities for utilizing mine / steel plant wastes
- Upgradation in the metallic charge
- Improvement in steel quality in terms of composition
- Reduction in capital / operational costs
- Increasing attention towards environment

Salient Features of SR Process

- Process is completely independent of coke
- Uses coal directly as reductant
- Requires at least two separate reactors – one for pre-reduction and other for melting
- Higher productivity than BFs due to higher mass transport rates and temperatures
- Gas exiting has high thermal and chemical energy (due to high temperatures and presence of CO) – which can be used to further reduction
- Involves three discrete steps – Pre-heating, Indirect reduction by CO gas and final reduction by carbon

Types of SR Processes

Processes	Capacity, tpa	Remarks
Vertical Shaft		
MBF	30,000-1,125,000	Covers very wide range
Corex	300,000-900,000	5 operating plants. First and leading SR process. Very high volumes of off-gas; some coke often used. Coal properties cannot be varied over a very wide range.
Finex	1,200,000-1,500,000	Process development complete. Very promising for relatively large scale production.
Tecnored	150,000	Process still under development. It is amenable to modular concept for increase in capacity
Bath Smelting Processes		
HIsmelt	600,000-1,200,000	Process almost ready for commercial exploitation.
Ausmelt	Upto 2,500,000	Process not proven so far.
Romelt	200,000-1,000,000	Russian process with tremendous potential, but no plants have been installed despite efforts, including in India and Japan.
Rotary Hearth Furnace (RHF)		
ITmk3	500,000	Commercial plant commissioned in early 2010. Slag separation from DRI by partial melting isa novel feature of this process.
4. RHF Combined with Melting / Smelting		
Inmetco *FastMelt*	60,000 150,000-1,000,000	Suitable for zinc-bearing iron ores. 2 operating plants mainly for smelting solid wastes from ISPs.

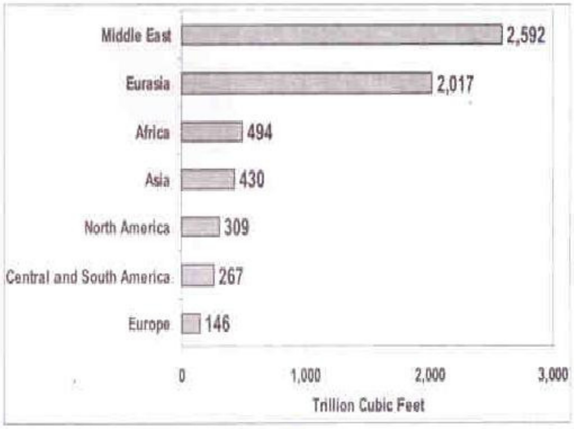
Drawbacks of SR Process

- **Very high quality coal required – increases cost**
- **Inefficient utilization of export gas due to two-stage operation**
- **Requires large number of stages to improve efficiency**

Salient Features of DRI Process

- **Gas based or coal based process**
- **Less dependence on coal and coke reserves**
- **Eco-friendly since gas based fuels are cleaner and more efficient**

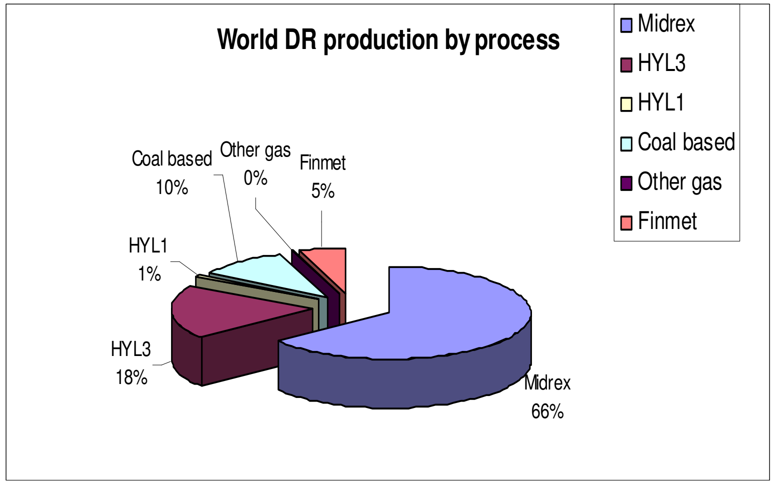
World Natural Gas Reserves



India's Natural Gas Reserve Estimates

	Initial estimate, Mt	Ultimate reserves, Mt	Recoverable reserves, Mt
ONGC	1688.32	942.28	523.01
OIL	251.00	170.00	110.00
Pvt./JV	933.59	511.76	466.94
Total	2872.91	1624.04	1099.95

Global Production Pattern of DRI Process



Country	Production, Mtpa (Rank)						
	1980	1990	2000	2002	2004	2006	2008
India	0	0.61	5.49 (3)	5.73 (2)	9.12 (1)	15.03 (1)	20.15 (1)
Venezuela	1.63 (1)	3.52(1)	6.41 (1)	6.84 (1)	7.82 (2)	8.42 (2)	7.14 (3)
Iran	0	0.26	4.53	5.28 (3)	6.43 (3)	6.93 (3)	7.39 (2)
Mexico	1.62 (2)	2.52 (2)	5.58 (2)	4.74	6.35	6.17	5.94
Saudi Arabia	0	0.57	3.05	2.31	2.21	2.58	4.53
Trinidad and Tobago	0	0.99 (3)	1.51	2.31	2.22	2.07	1.60
Canada	0.88 (3)	0.73	1.12	0.17	1.09	0.45	0.74

Difference between Midrex & HYL

Sl. No.	Item	Midrex	HyL III
1.	Type of process	Continuous shaft furnace	Continuous shaft furnace
2.	Type of reductant	Natural gas	Natural gas
3.	Type of oxide feed	Pellets and sized ore	Pellets and sized ore
4.	Type of reformer	Catalytic reformer	Heater in place of reformer
5.	Type of reforming	Catalytic reforming(CH4 react with Top gas (H2 + CO_2) & some amount of insitu reforming	Partial oxidation & Steam reforming & insitu reforming
6.	Furnace operating pressure	Operates at slightly above atmospheric pressure(1.5 bar max)	Operates at 4-5 bar (g)
7.	Furnace operating temperature, ^{0}C	~950	~1000

Drawbacks of DRI Processes

- High price and difficulty in transport over long distances
- Limited and localized availability
- Contains gangue, giving rise to higher slag volume during steel making
- Residual FeO in DRI requires carbon and results in higher power and refractory consumption
- Can result in lower productivity in EAFs

Current status of Iron making processes (Proven)

Process	Remarks
Blast Furnace	High capital cost, requires metallurgical coke
Corex	Needs to use export gas, high capital cost
Midrex	Requires natural gas
HYL	Requires natural gas

Current status of Iron making processes (At commercialization)

Process	Remarks
Hismelt	Some export energy
FINMET	Not optimized
RHF - Melter	Low productivity, operational problems
CIRCOFER	Not optimized

Current status of Iron making processes (Under development)

Process	Remarks
FINEX	Need to use export gas
ITmk3	Low productivity

Conclusions

- Currently 60% iron metallics in steel production is through hot metal
- Entire quantity of hot metal supplied by BFs
- By 2015, hot metal proportion expected to come down to 50%, balance as solids
- Value in Use (VIU) – the key to differentiate sources of iron
- SR expected to have higher VIU than DRI, since iron is in molten state
- Corex process has been applied successfully by small producers
- Other processes of DRI and SR (such as HIsmelt, Finex, etc) – expected to come into consideration very soon due to deterioration in quality of raw materials

Thank you