

Reduction in Charge Requirements of Hismelt Iron-Making Process in Indian Context

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ABSTRACT: Worldwide steel production has increased by about 25% in the last 10 years. Much of the growth has occurred in China, India, and other developing countries. In the context of Indian steel plants, much of the growth has been through BF-BOF(90%) followed by a number of other routes DRI-EAF, COREX route e.t.c. The paper is aimed at discussing the typical composition of the charge which may lead to reduction in charge requirements of Hismelt iron-making process in Indian context, in case of Hismelt process.

Keywords: Hismelt, SRV, COREX, OBM, SSPP

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I. INTRODUCTION

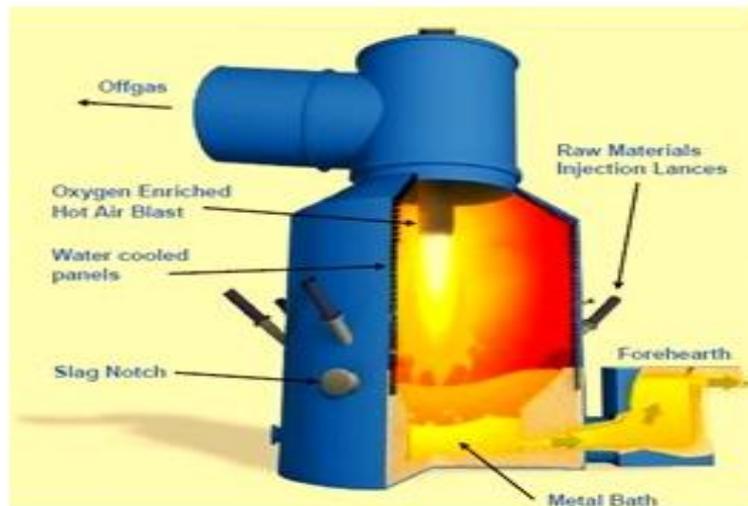
A number of problems in the BF-route in the Indian scenario are as follow:

- Poor quality of domestic coking coals leading to a high dependence on coal imports.
- High Al_2O_3 content of ore degrading the sinter quality.
- High Si content in hot metal due to unfavourable cohesive zone formation due to poor sinter properties.

This necessitates the requirement of alternative iron-making technology. Hismelt(Ironmaking) process is one such method of solid injections using high speed lances which ensure that the capture efficiency in the melt is high. The process allows the use of non coking coal and iron ore fines with significant impurities. The core of the Hismelt process is the smelt reduction vessel (SRV) which has a refractory lined hearth and water cooled upper shell. The process is carried out in this vessel. The refractory hearth contains the molten iron bath and liquid slag. The main product of the process is liquid iron or hot metal which can be used in steel melting shop or cast in pig casting machine to produce pig iron. The byproduct of the process is slag and the off gas.

Driving force behind Hismelt

- Ability to utilise cheaper and more abundant raw materials like non-coking coals and non-agglomerated ores.
- Smaller economic plant sizes.
- Competitive capital and operating costs.
- Environment friendly- elimination of coke ovens and sinter/pellet plants.
- Flexibility of operation.



Courtesy: Kwinana, Australia

The origin of the HIs melt process is traced back to the bottom blown oxygen converter process (OBM) and the evolution of the combined blowing steel making process developed by KlöcknerWerke at their Maxhütte steel works[1]. CRA (now Rio Tinto) formed a joint venture in 1981 with KlöcknerWerke to pursue the steel making and smelting reduction technologies. Trials were conducted in a 60 tons OBM converter to demonstrate the fundamentals of the smelt reduction process. The successful testing of the smelt reduction concept led to a small scale pilot plant (SSPP) of capacity around 12000 tons per annum located at the Maxhütte steel works. The design of the SSPP was based on a horizontal rotating SRV that used bottom tuyeres for injection of coal, fluxes and iron ore. The SSPP operated from 1984 to 1990 and proved the viability of the technology.

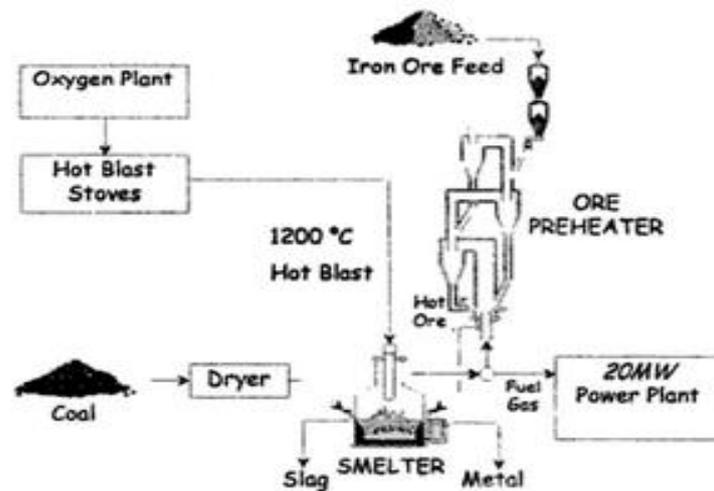
Next stage of the process development was the HIs melt Research and Development Facility (HRDF) constructed at Kwinana, Western Australia. Construction of the HRDF with a design capacity of 100,000 tons per annum, commenced in 1991. The main objective of the HRDF was to demonstrate the process and engineering scale up of the core plant and to provide operating data for commercial evaluation. The original SRV configuration for Kwinana was a direct scale up of the SRV of SSPP and was based on a horizontally shaped vessel capable of rotation through 90 deg. The horizontal vessel was operated from October 1993 to August 1996. Whilst scale-up of the process was successfully demonstrated, the complexity of engineering a horizontal vessel limited its commercial viability.

To overcome this deficiency a design was developed for water cooled vertical vessel. Design and engineering for the vertical SRV was completed in 1996. The main improvements incorporated into the design included a stationary vertical vessel, top injection of solids, a simplified hot air blast lance, a fore hearth for continuous tapping of metal and water cooled panels to overcome refractory wear problems. HRDF vertical smelt reduction vessel was commissioned in the first half of 1997 and operated through to May 1999. The vertical vessel demonstrated major improvements in terms of refractory wear, reliability, availability, productivity and simplicity in design. This vessel addressed all the key requirements for a successful direct smelting iron making technology – combining a high level of technical achievements with simple engineering concepts and plant technology. This stage of operation confirmed that the process was ready to be scaled up to level of a commercial plant.

A joint venture was formed in 2002 between the Rio Tinto (60%), Nucor Corporation (25%), Mitsubishi Corporation (10%), and Shougang Corporation (5%) for the purpose of constructing and operating an 800,000 tons per annum HIs melt plant. Located in Kwinana, Western Australia, the merchant pig iron facility was designed and engineered with a 6 meter hearth diameter SRV. Construction of the plant was started in January 2003. Cold commissioning commenced in the second half of 2004 while the hot commissioning was carried out in second quarter 2005. The plant had achieved a production rate of 80 tons of hot metal per hour in early 2008 with a coal rate of 810 kg per ton of hot metal. The plant is presently in the closed down condition.

To develop the HIs melt technology further, Rio Tinto has signed a development agreement with a Chinese steelmaker. This involves relocating some HIs melt plant equipment from Australia to a new HIs melt facility to be built in China. The new plant is expected to be commissioned in 2014. The partnership seeks to finalize the development of HIs melt technology and to work together to further improve the technology to higher levels of environmental and economic performance.

Process[2]



Courtesy: HIs melt Corporation(Kwinana, Australia)

The basic mechanism of the process is the reduction and smelting of the iron bearing ores with the dissolved carbon in the bath. The process uses high velocity injection of coal and ore into the melt through downwardly angled water cooled injection lances. Injected coal after heating and devolatilization dissolves to maintain around 4 % carbon in the molten metal and replenish the carbon used in the reduction reaction. Injected iron ore fines are injected deep into the bath where they are reduced instantly on contact with carbon dissolved in the bath for smelting to take place. This reduction reaction produces iron (Fe) and carbon monoxide (CO). The lower part of the SRV is maintained at low oxygen potential to allow this reduction reaction to occur and the reaction kinetics balance out at around 5 % to 6 % of FeO in the slag. Reaction gas (CO) and coal devolatilization products which are generated from deep within the bath form a fountain of mostly slag and some metal. Heat supply to maintain the necessary thermal balance comes by the combustion of reaction gas (mostly CO) in the upper part of the SRV. Oxygen enriched (typically 35 %) hot blast at 1,200 deg C is introduced through a top lance and efficiently burns the gases generated within the bath and releases large amounts of energy. This combustion occurs in the relatively oxidizing region in the upper section of the SRV. The heat transfer between the upper (oxidizing) regions to the lower (reducing) region is achieved in such a way that the oxygen potential gradient is maintained. This is done through large amounts of liquid splash moving between the two regions. Liquid slag and metal splash acts as a carrier of the heat. The 'natural' 5 % to 6 % FeO level in the slag in conjunction with the metal carbon at 4 % creates conditions for strong partition of phosphorus from metal to slag. Typically around 80 % to 90 % of phosphorus goes to slag. Coal performance has virtually no dependence on particle morphology, since the coal is ground fine for injection.

Innovations till date

- Intermediate levels of pre-reduction tested by blending ore fines with DRI
- Oxygen reduction of hot air blast (upto 30% oxygen content) utilised to increase productivity.
- Post-combustion in the range of 60-80% achieved routinely with cold iron ore fines as ferrous feed, coal rates of around 880 kg/thm with an ore preheater.
- Significant portion of pilot plant operation utilising ore fines with high P content (0.12 wt.%) leading to 85-95% P transferred to slag phase.
- Mixture of blast furnace dust, LD dusts, sludges, mill scale dust, pellet fines and casthouse dusts blended with iron ore fines and injected without any agglomeration technique, resulting in more than 97% productivity.
- Economic recovery of Zn and Pb from the above dust.

II. RESULTS AND DISCUSSION

Table1. Typical charge composition for Hismelt process

Ferrous charge	% Fe	%C	Silica+Alumina (%)
Fines(0.075% P)	61.0		7.5
Fines(0.12% P)	62.4		5.6
DRI	90.5		5.5
Steel plant wastes	53.3	10.1	5.5

Table2. Coal grades for Hismelt process

Coals	Fixed %C	Volatiles (%)	Ash(%)	CV(GJ/t)
Coal A	73.2	9.8	12.0	28.3
Coal B	69.3	16.8	6.9	30.5
Coal C	68.8	25.7	4.8	32.9
Coal D	49.9	38.5	9.4	30.2

Mass and energy balance of typical HM and slag composition

Working temperature: 1465⁰C-1495⁰C

Table3. Composition of Hot metal, at present(Basis: 1 T of HM)

Elements (wt.%)	C	Si	S	P	Mn
Mass%	4±0.2	-	0.1±0.02	0.03±0.01	0.1

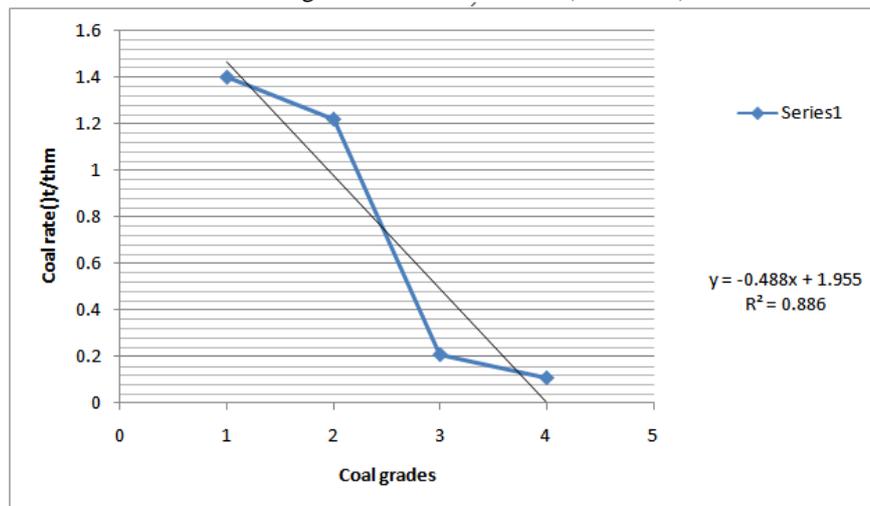
Table4. Composition of Hismeltslag(at present)

elements	FeO	SiO ₂	CaO	Al ₂ O ₃	P ₄ O ₁₀	MgO	V ₂ O ₃	TiO ₂	Slag viscosity
Mass%	5	30	37	15	0.8	10	-	0.7	3.3 poise

Table5. Variation in coal rates(t/thm) for different grades of coal with fines(0.075% P)

Grade	D(1)	C(2)	B(3)	A(4)
Coal rate	2.3	2.1	1.84	1.62

Figure1. Graphical representation of variation in coal rates(t/thm) for different grades of coal with fines(0.075% P)



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Table6. Coal rate(t/thm) with fines(0.12% P)

Grade	D(1)	C(2)	B(3)	A(4)
Coal rate	2.78	2.54	1.53	0.88

Figure2. Graphical representation of variation in coal rates(t/thm) for different grades of coal with fines(0.12% P)

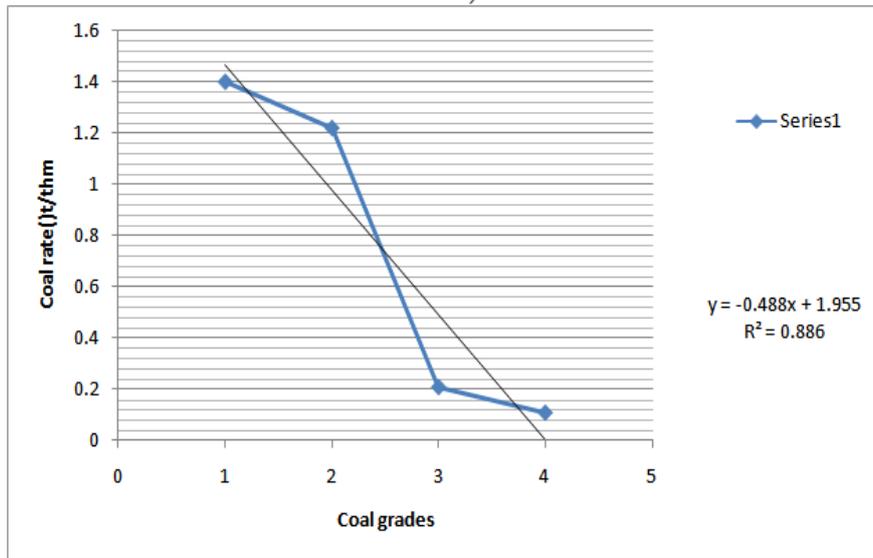


Table7. Coal rate(t/thm) with DRI

Grade	D	C	B	A
Coal rate	2.65	2.12	1.97	0.32

Figure3. Graphical representation of variation in coal rates(t/thm) for different grades of coal with DRI

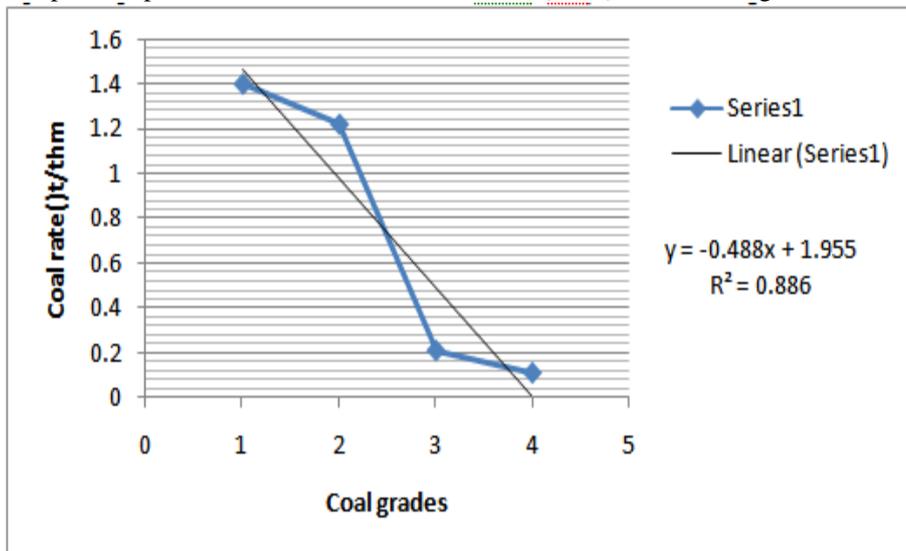


Table8. Coal rate(t/thm) with LD dust, sludge and pellet fines

Grade	D(1)	C(2)	B(3)	A(4)
Coal rate	1.4	1.22	0.21	0.11

Figure4. Graphical representation of variation in coal rates(t/thm) for different grades of coal with LD dust, sludge, pellet fines.

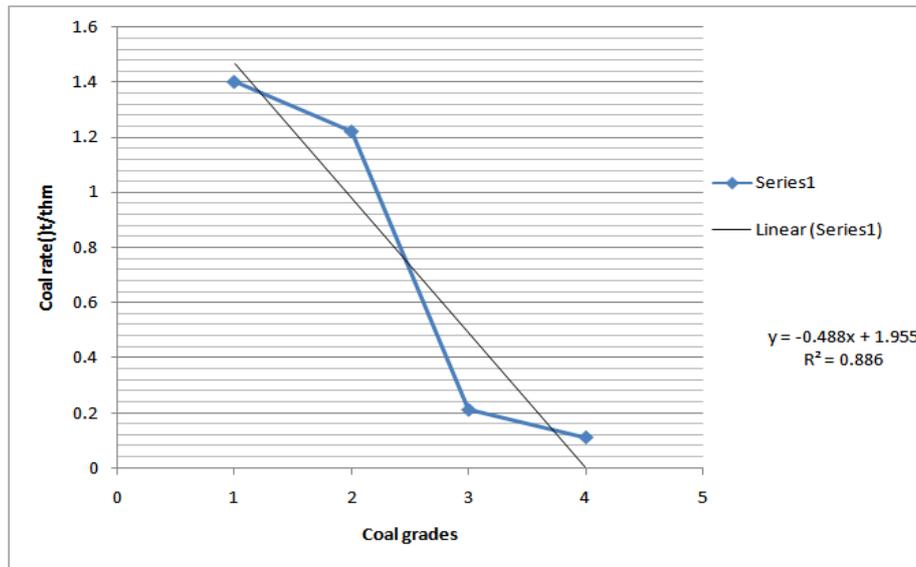


Table9. Comparison of Demand for Oxygen between BF, COREX and Hismelt(for same composition of charge)

Route	BF	Hismelt	COREX
Oxygen demand(in t)	7.8	Only preheated air	0.5-2.1

Table10. Comparison of Electricity requirement between BF, COREX and Hismelt(for same composition of charge)

Route	BF	Hismelt	COREX
Electricity requirement(in kWh)	210	109	125

Table11. Comparison of Heat from off-gases between BF, COREX and Hismelt(for same charge composition)

Route	BF	Hismelt	COREX
Heat from off-gases(in GJ/thm)	14.2	7.352	11.5-12.9

Table12. Comparison Specific energy consumption(SEC) between BF, COREX and Hismelt (for same charge composition)

Route	BF	Hismelt	COREX
SEC(in GJ/thm)	11-15	4.1	11.5-12.9

Table13. Off-gas analysis between HM quality of BF, COREX and Hismelt under Indian conditions(for same charge composition)

Gas analysis(in %)	BF	Hismelt	COREX
CO	20-22	53-56	40-45
CO ₂	15-18	7-13	30-32
H ₂	-	6.4-7.5	18-20
CH ₄	-	-	1.7-2.1
N ₂	50-53	32-36	-
O ₂	0.1-0.4	0.1-0.3	-

Table14. Comparison between HM quality of BF, COREX and Hismelt under Indian conditions(for same charge composition)

Typical analysis(%)	BF	Hismelt	COREX
C	4.5	4.24±0.13	4.5±0.3
Si	0.5±0.3	<0.012	0.2±0.01
Mn	0.4±0.2	<0.015	0.06±0.01
P	0.09±0.02	0.0025±0.01	0.07
S	0.04±0.02	0.08±0.05	0.015
Temperature	1430-1500 ⁰ C	1420 ⁰ C	1470 ⁰ C-1520 ⁰ C

Table15. Comparison between slag quality of BF, COREX and Hismelt under Indian conditions (for same charge composition)

Typical analysis(%)	BF	Hismelt	COREX
CaO	34-43	45	36
SiO ₂	27-38	30.6	31
MgO	7-15	10.9	12.8
TiO ₂	-	0.4	0.453
Al ₂ O ₃	7-12	15	15.5
FeO	0.2-1.6	5.6	0.254
P ₂ O ₅	-	1.7	-
MnO	0.15-0.76	-	-

Table16. Amounts of charge for Hismelt (in Indian conditions)

Charge(kg/thm)	Option 1 (without ore preheating, at present)	Option 2 (with ore preheating, at present)	Option 1 (with present composition, without ore preheating)	Option 2 (with present composition, with ore preheating)
Ore fines	1650	1660	1540	1560
Crushed charcoal	800	700	659	542
dolomite	25	40	24.5	32
Calcined lime	50	47	54.1	48
Electricity consumption(kWh)	111			108

III. CONCLUSION

From a number of mass and energy balance calculations, the composition of charge (as shown in above table) is found to be optimum with high quality of P-deficient hot metal and optimum electricity and specific energy requirements with high amount of heat from off-gases. This may be one way of making the process more attractive to the Indian Steel plants.

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