COKE QUALITY FROM COKE PLANTS UTILIZING THREE DIFFERENT PRODUCTION METHODS (1)

Hardarshan S. Valia(2)

Summary

Ispat Inland's No. 7 Blast Furnace has used coke produced from three different modes of production. In 1992, Ispat Inland started shutting down its coke plants. As a result, No. 7 B.F. started operation on 100% purchased coke from domestic by-product cokemaking source. Periodically, a second coke upto 25% of the B.F. requirements was used. One of the coke used was from a stamp charged Non Recovery cokemaking source from China. In March of 1998, SUN commissioned a new Heat Recovery coke facility, where coke and electricity is produced for Ispat Inland. The coke plant is operated and managed by Indiana Harbor Coke Facility (IHCC), East Chicago, Indiana. Coke production and coke quality from the three cokemaking processes are described. As compared to the coke from the By-Product facility, the coke from stamp charged-Non Recovery and Heat Recovery processes possessed higher cold and hot strength properties, higher cell wall thickness, and higher pyrolytic carbon. The coal blend volatile matter content (dry basis) for Heat Recovery and By-Product cokemaking blends was about 30% and for stamp charged Non Recovery cokemaking blend was 22.5. In addition to proper coal blend selection, the slow heating rate, longer soak time, and higher pyrolytic carbon may have contributed to improvements in coke strength properties for coke produced from Heat Recovery/stamp charged-Non Recovery process.

Keywords:

Coke, Production, Quality

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(2) Staff Scientist, Ispat Inland Inc., R & D Laboratories East Chicago, IN 46312, USA

1. INTRODUCTION

The commercial metallurgical cokemaking process can be divided in to three categories: a)By-Product Cokemaking, b)Non-Recovery Cokemaking, and c)Heat-Recovery Cokemaking. The majority of coke produced in the world comes from wet-charge, by-product coke oven batteries where the coal is carbonized in slot-type ovens. The coal is heated from side walls, under a positive pressure in a reducing atmosphere and the by-products are recovered. One example of a by-product slot oven coke plant is shown in Figure 1. In the Non-Recovery coke plants, originally referred to as beehive ovens, the coal is carbonized in large wide oven chambers. The carbonization takes place from the top by radiant heat transfer and from the bottom by conduction of heat through the sole floor. Primary air for combustion is supplied in to the oven and partially carbonized gases are taken through down-comers to heat the sole of the oven. The gases finally exit through a common tunnel in to a stack and in to the atmosphere. China is the largest producer of metallurgical coke in the world and in 1997, of the total coke production of 139 million ton, 71 million ton was from by-product coke plants and 68 million ton from Non-Recovery coke plants.(1) One example of Non-Recovery coke production from Shanshi province is shown in Figure 2. Recently, a third type called Heat Recovery cokemaking has come in to operation. The process is similar to Non-Recovery but the waste gas exits in to a waste heat recovery boiler (Figure 3) which converts the excess heat in to steam for power generation; hence, its called Heat Recovery.

In 1992, Ispat Inland started shutting down its By-Product coke plants and used 100% purchased coke from domestic by-product cokemaking source. Periodically, a second coke up to 25% was also used. One of the coke used was from a stamp charged-Non Recovery cokemaking source from Shanshi Province of China. In March of 1998, SUN commissioned the Heat recovery cokemaking facility on-site where coke and electricity is produced for Ispat Inland. SUN utilized the Jewell Thompson Non Recovery coke ovens concept. The coke plant is operated and managed by Indiana Harbor Coke Company (IHCC), East Chicago, Indiana. The Heat Recovery Coke Facility is owned and operated by the Indiana Harbor Coke Company (IHCC) - a subsidiary of SUN. The coke plant is comprised of four batteries (A, B, C, and D) made up of 67 ovens per battery (268 ovens) so as to produce 1.2 million ton of screened coke per year which is delivered by belt to Ispat Inland's No. 7 B.F. The hot gases from the battery are fed into waste heat boilers (4 boilers per battery) producing about 120 Kg/s of steam and a typical power generation of 75 MW. The spent gases pass through a desulfurization unit and bag house before exit through the stack.(2-3)

Figure 1. An example of a By-Product Coke Battery

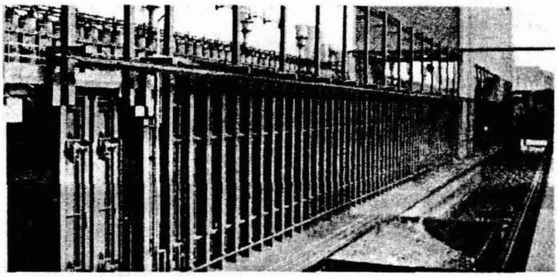


Figure 2. An example of a Stamp Charge NR Battery

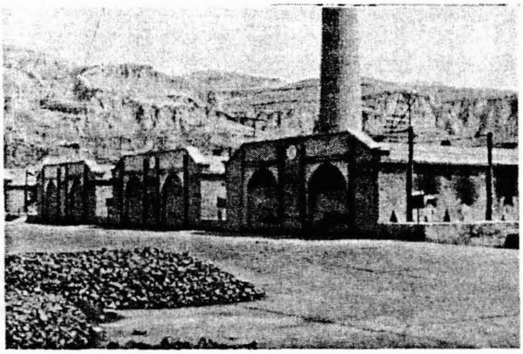
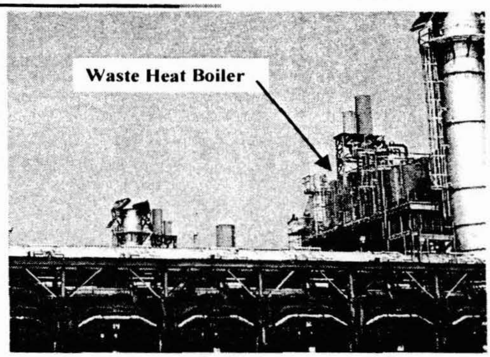


Figure 3. SUN Heat Recovery Coke Battery



In this paper, coke quality from the new Heat Recovery Facility (IHCC-SUN), a domestic slot oven by-product facility, and a stamp charged, Non-Recovery facility (Shanshi province, China) will be described. The general design parameters and operating parameters for the above-mentioned three batteries are shown in Table I.

Table I. Design and Operating Parameters

	Slot Oven	IHCC-HR	Stamp NR
Width, mm	457.2	4572	3000
Height, mm	6000	2438.4	2800
Length, mm	16662	13716	22600
Coal Height, mm	5721	1016-1143	1800
Coal Weight, metric ton	31.75	36.3-40.8	136-181.4
Gross Coking Time, h	18	48	252

2. COKE QUALITY:

Coke quality parameters are shown in Table II and the graphical presentations are shown in Figure 4-10. The coke quality text and figures are reproduced from Reference 4. For this presentation, the Heat Recovery coke will be called IHCC-HR Coke. Slot Oven by-product coke, from one domestic source, that was used at No. 7 BF, will be called Slot oven coke. Stamp charged Non Recovery coke from one particular plant in Shanshi province of China, used at Ispat Inland, will be called Stamp charge NR coke. IHCC-HR coke quality represents average of start-up from A, B, C, D, and Full Battery Composite samples (beginning March 1998). Also, shown are coke quality values from six oven test from the blend change that took place during later part of 1998.

Coke quality parameters (Table II) are divided into four categories:

a) cold strength properties,
b) hot strength properties,
c) structural –textural properties, and
d) coke chemical properties.

Table II. Coke Quality Parameters

Quality	IHCC-HR	Slot Oven	Stamp NR
CSR	70(70) = Av. 70	62	69
CRI	20(21) = 21	24	22
Stability	64(66) = 65	60	72
Hardness	71(71) = 71	67	73
M40	85(87) = 86	84	90
M10	6.3(5.9) = 6.1	7.4	4.8
Mic. Slope	0.57(0.52) = 0.55	0.70	0.27
Porosity,%	49(50) = 50	48	43
Coke Size,mm	52(56) = 54	53	64
Pyrolytic Carbon,%	2.2(1.4) = 1.8	0.7	2.0
T.Inerts,%	23(28) = 26	21	32
Cell Wall Thick.,micron	174(ND)	127	180
VM,%	0.50(0.52) = 0.51	0.53	0.52
Ash,%	8.7(8.8) = 8.8	7.2	10.2
Sulfur,%	0.66(0.60) = 0.63	0.74	0.43
Phosphorus, %	.013(.015) = .014	0.019	0.010
Alkalies,%	.166(.160) = .163	0.210	0.08
Granular Carbon ,%	46(40) = 43	26	15
Base/Acid	0.20(0.18) = 0.19	0.23	0.11

(*) values denote change in blend during later part of 1998.

a) Cold Strength Properties – Stability and M40:

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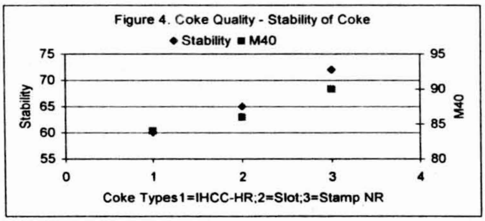
The Stamp Charge NR coke is characterized by extremely high stability value (72) followed by IHCC-HR coke (65); the Slot Oven coke has the lowest stability value (60). Somewhat similar trend is apparent for M40 values (Figure 4).



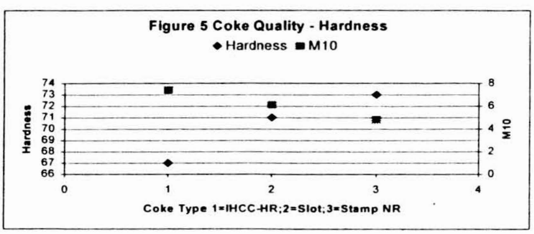
The Slot Oven coke was produced from a coal blend of 29% volatile matter (db) with a predicted coke stability value of 59. The IHCC-HR coke was produced from a coal blend of 30% volatile matter (db) and later from a coal blend volatile matter (db) of 27.5%; the predicted coke stability values were 60 and 62, respectively. It seems that the IHCC-HR actual stability values were about 4 points higher than the predicted coke stability values. Hence, Heat Recovery process resulted in an increase in stability by about 4 points. This is also apparent when one examines the carbonization results on a particular blend (e.g. blend B). This blend was initially carbonized during the early coal blend design phase at Jewell Thompson ovens in Vansant, Virginia, before the start up of IHCC Battery, and it was also carbonized in a slot oven-pilot facility. The results are shown below (2):

	B Blend Coke Via Non Recovery	B Blend Coke via Slot Oven
Stability	62.2	58.5
Hardness	69.7	68.3
Coal VM	29.5	29.5

Thus, it seems that for a coal blend of about 30%VM, the HR/ NR process helps improve stability by about 4 points. In the case of Stamp Charge NR coke, the coal blend was of higher rank (22.5% VM, db; 1.31% reflectance) with higher predicted coke stability value (64). The 8-point improvement is due to the combined effect of Non Recovery process and compaction of the coal bed.

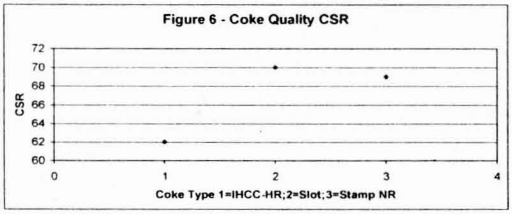
b)Cold Strength Properties – Hardness and M10:

The Stamp Charge NR, and the IHCC-HR cokes, are characterized by high hardness values (73 and 71), whereas, the Slot Oven coke shows the lowest hardness value (67). A somewhat similar trend is apparent for M10 (Fig.5) and Micum slope (Table II).



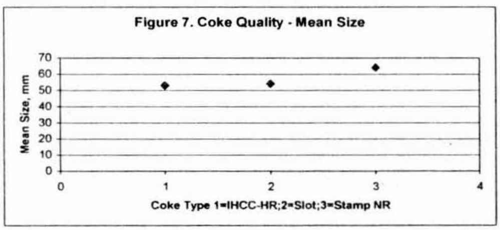
c)Hot Strength Properties – CSR:

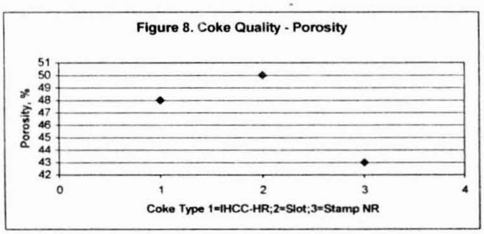
The CSR values (Figure 6) are higher for IHCC-HR and Stamp Charge NR coke when compared with the Slot Oven coke (about 70 versus 62). Although the slot oven coke produced 62 CSR, the earlier values were about 66. The predicted CSR for IHCC-HR blend, using Ispat Inland CSR prediction for slot oven coking (5), was 67. Hence, the Heat Recovery process resulted in an increase in CSR by about 3 points. In case of Stamp Charge NR coke, the predicted CSR was 76 but the actual CSR was 69. The discrepancy in CSR may be related to coal blend chemical change.

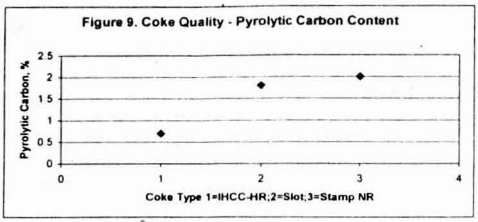


d)Coke Structural-Textural Properties:

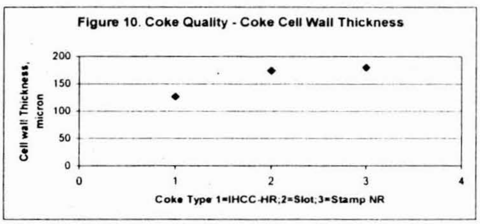
Coke size and coke porosity of IHCC-HR and Slot Oven coke are similar (Figures 7 and 8). However, the Stamp Charge NR coke is characterized by large size and extremely low coke porosity and also high content of total inerts (Table II). Pyrolytic carbon content is higher for both IHCC-HR and Stamp Charge NR cokes (Figure 9). Granular carbon content is high for IHCC-HR coke (Table II) which is mostly a reflection of coal type.







It should be noted that as compared to Slot Oven coke, both IHCC-HR and Stamp Charge NR cokes have higher cell wall thickness (Figure 10). Stamp Charge NR coke was produced from inert-rich (32%), high rank (22.5% VM; 1.31 maximum vitrinite reflectance), and high fluidity blend (Maximum Fluidity=7872 ddpm; Fluid Range=103 Deg. C) which may have partly contributed to extreme high strength properties and large coke size.



It should be noted that the cell wall thickness for IHCC-HR (as shown in Figure 10) is on the same blend but carbonized at Jewell Thompson Non Recovery oven in Vansant, Virginia (2).

e)Coke Chemical Properties:

The chemical composition of coke is mostly a function of the coal quality. Hence, not much can be said about the coke chemical properties except that Stamp Charge NR coke was produced from coal blend with high coal ash (acidic composition), low sulfur, low alkalies, and low phosphorus which, along with high fluid range, are beneficial to CSR.(5)

3. DISCUSSION

As noted earlier, Heat Recovery and stamp charged Non Recovery coke has better stability, Hardness, CSR, thicker cell wall, and higher pyrolytic carbon content. The improvement in coke strength properties, besides the role of proper coal selection, are due to following factors:

a)Slow Heating Rate and Longer Soak Time:

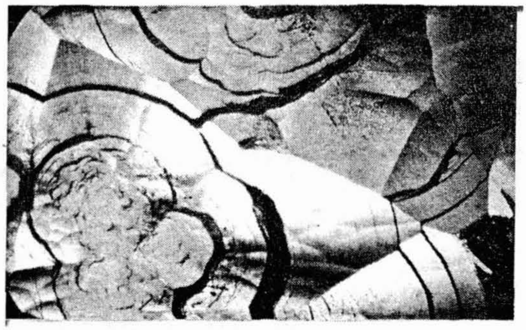
In Heat Recovery/stamp charged Non Recovery process, the slow heating rate has contributed to improvement in coke strength properties in following ways: Low coke rate, at an earlier stage of carbonization for higher bulk density bed, would result in lower dilatation, more retention of the low molecular weight decomposition products, thereby, impacting the transmission of inter-granular pressure on to the semi-coke layer. This would result in controlling and the formation of minor lateral micro-fissures. However, at the later stage of carbonization, it would help lower the temperature gradient in the post-plastic temperature zone and thereby, controlling the formation of major fissures.(6) This would account for the improvement in impact-resistant coke strength coke strength properties. Low cooking rate, coupled with retention of low molecular weight decomposition products due to high bulk density of coal (7), would also provide longer time for structural ordering, allowing anisotropy to appear at lower temperature.(8) This would imply better wetting, bonding, inter- and intra-particle interaction and subsequently the development of thicker cell wall structure in the coke. The net effect will be improvement in abrasion strength and hot strength properties.

The higher soak time in Heat Recovery/stamp charged Non Recovery process would further help in structural ordering and densification of coke mass resulting in further improvement in CSR and reduction in structural variability of CSR in the oven.

b)Pyrolytic Carbon Content:

As noted earlier, by-product coke has the lowest pyrolytic carbon content whereas, stamp charged Non Recovery coke has the highest amount of pyrolytic carbon, and the Heat Recovery coke has intermediate amount of pyrolytic carbon. The highest amount of pyrolytic carbon in stamped charge Non Recovery coke, characterized by high coal bulk density, is due to cracking of the volatiles passing through a thicker bed of semi-coke at higher temperature, with a longer passage time. However,in by-product cokemaking, the volatiles escape easily through a coal bed of only 9 inch from the center of the charge towards the coke oven wall. One example of pyrolytic carbon form in Heat Recovery coke is shown in Figure 11. The pyrolytic carbon deposition would attribute to improvement in CSR and reduction in coke reactivity. Vandazande(9), Shigeno and Evans(10) attribute carbon deposition to improvement in CSR and CRI when methane gas is cracked in hot coke bed.

Figure 11: A large pyrolytic carbon nodule in Heat Recovery coke



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