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PILOT SCALE CARBONIZATION STUDIES ON POLISH BELLVIEW COALS FOR METALLURGICAL COKEMAKING

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Abstract

The pilot scale carbonization of the normally charged bituminous Polish Bellview coal blends was conducted in a 250kg capacity coke oven with a bulk density of 800kg/m^3, flue temperature of 1250°C and coking time of 18 to 20 hours. The micum drum test conducted on Bellview A and B cokes gave M_{10} abrasion resistance of 11.40% and 15.40% and M_{40} resistance to fragmentation of 77.80% and 70.80% for Bellview coke A and B, respectively. The results of this study showed that Bellview A coal blend is of a higher bituminous grade than Bellview blend B, though its micum indices do not meet the specification of 9% (maximum) M_{10} and 78% (minimum) M_{40} for blast furnace ironmaking at the Nigerian Ajaokuta steel plant. It is however expected that the small deviations of +2.4% and -0.2%, in the M10 and M40 of Bellview B coke may be eliminated during industrial scale cokemaking under a higher static load and the application of coking improvement techniques such as pre-heating and stamp charging .

Keywords: coal; density; carbonization; coke.

1. Introduction

Coke is an essential input in blast furnace iron production. Consequently, the volume of coke produced and used depends on the blast furnace activity. For instance, as at 1973 when the blast furnace iron output was 96.2 million in the United States, blast furnace coke consumption was 60.7million tons [1].

For coal to be converted to coke, it has to undergo molecular degradation of its tri-dimensional macromolecular networks consisting of aromatic and hydro-aromatic clusters held together by alkylic chains and strong bonds. In cokemaking, the molecular degradation is caused by pyrolysis. When coal is heated, it softens when heat breaks the coal structure producing liquids and gases. The evolved low molecular weights components of the coal may escape as gases, while some molecules may condense as a complex mixture of liquids called tars and the large molecular weight species may re-combine and solidify as coke [2].

From low to high rank coal, the oxygen content decreases and the cross linking due to oxygen group is replaced by hydrogen bonds in the intra-molecular network. Since the hydrogen bond are weaker than oxygen bonds, on heating high ranks coals show higher plasticity than low rank coals [2,3]. Though chemical analysis of coals do not indicate whether a coal will be coking or not, some aspects of coal composition are useful in selecting coals for metallurgical cokemaking.

A coking coal is required to have a low ash content because a large amount of inorganic material can dilute the plastic stage, adversely affecting coke formation. The coal should also contain low sulphur to reduce the amount of this heteroatom that may get into iron and reduce its mechanical strength[2,3,4]. For cokemaking, a careful selection of coal charge bulk density, coking flue temperature and coking time is necessary to control the generation of internal pressure in the coke oven which may lead to the damage of coke oven wall. These factors also influence coke lateral contraction which determines coke pushing efficiency that influences battery life and cost of operation [5].

2. Materials and methods

2. 1 Materials

Drums of Bellview coal blends A and B imported from Poland by Bellview Nigeria Ltd.

2. 2 Methods

The coal sample was carbonized in a 250 kg coke oven plant and the coke produced was subjected to screen distribution analysis and micum drum tests to determine the micum strength.

2. 2. 1 Pilot scale coal carbonization

The as-received coal was subjected to further crushing to obtain a sieve analysis such that >3mm size fraction is >70% and < 0.5mm is $\leq$ 35%. The bulk density test was performed to obtain a bulk density of 800kg/m^3.The coal charge was then dropped into the oven from a height of 5.2m to the plant level. During the carbonization, the temperatures of the six heating flues were maintained at 1,250°C by careful adjustment of air/liquefied petroleum gas ratio, at a heating rate of 2 to 3^{o}C/min. The charge temperature rose progressively from 60°C to about 1250°C within a carbonization period of 18 to 20 hours. The coke produced were pushed into a quenching facility where cooling was done for about 3 hours by water circulating in the system but not in direct contact with the coke.

The coke produced was then stabilized by dropping the coke from a hopper placed at a height of 5.6m. Afterwards, the stabilized coke were screened through round hole sieves 0 – 10, 10 – 20, 20 – 40, 40- 60, 60 – 80 and + 80mm in a vibrating screening machine. For micum test, 50kg sample obtained from selected fractions specified proportions was charged into a micum drum where it was subjected to rotation at a rate of 25 revolutions per minute for 4 minutes. The coke product of this test was then screened again on the vibrating screen machine to determine the M_{10} and M_{40} indices that indicate coke mechanical strength. The carbonization conditions used are presented in Table 1, while the results of screen distribution analysis and micum drum tests are shown in Tables 2 and 3.

Table 1: Carbonization conditions for Bellview coals

S/No	Coking parameters	Bellview A	Bellview B
1.	Weight of charge (kg)	212.10	129.35
2.	Bulk density (kg/m^3)	800	800
3.	Flue temperature (^{0}C)	1,250	1,250
4.	Carbonization time (hr)	18	20

Table 2: Screen Distribution Analysis of Bellview Coke

		Bellview A		Bellview B	
S/N	Sieve Sizes (mm)	Wt (kg)	%	Wt (kg)	%
1	-10	13.10	9.41	8.85	7.53
2.	+10-20	2.85	2.05	3.40	2.89
3.	+20-40	9.85	7.07	13.75	11.69
4.	+40-60	24.05	17.27	32.00	27.21
5.	+60-80	37.60	27.00	35.30	30.02
6	+80	51.80	37.20	24.30	20.66
	Total weight retained	139.25		117.60	

Tables 3: Weight of Bellview Coke retained on Sieve after Micum drum test

S/No	Sieve Sizes (mm)	Bellview A (Kg)	Bellview B (Kg)
1.	-10	5.70	7.70
2.	+40-60	15.85	18.60
3.	+60-80	19.45	15.15
4.	+80	3.60	1.65
5.	Micum 10 (M10) %	11.40	15.40
6.	Micum 40 (M40) %	77.80	70.80

3 Results and discussion

3 .1 Results

The carbonization conditions, the screen distribution analysis and results of micum drum tests are presented in Tables 1, 2 and 3, respectively.

3 .2 Discussion

The volatile matter of 31.80% and 31.30% determined for Bellview A and B, respectively exceed the 20% volatile for coals that produced excessively high internal wall pressure during carbonization in UK coke Research Establishment (CRE) moveable-wall oven tests [6,7]. It has been shown that coal blends such as Bellview with volatiles (daf) exceeding 26%, are unlikely to produce high coking pressures. The G-coking capacity of 0.97 and 0.93 determined for Belview A and B, respectively, also showed that the two blends may not give rise to high internal wall pressure during carbonization [7]. These results thus suggest that Bellview coals are not susceptible to producing high internal pressure in the coke oven.

The bulk density of 800kg/m^3 used for the normally charged Bellview coals is similar to 800 to 820kg/m^3 employed at CRE for normal top charging of coals. This value of bulk density has been reported to offer a greater margin of safely as regards internal pressure generation than opting for the mean density of 720 to 750 kg/m^3 [7]. The bulk density of coal charge has been found to have great effects on internal pressure generation in the coke oven. It has been suggested that coking pressure is related to the fifth power of bulk density [7]. The successful carbonization of Bellview coals showed that the bulk density selected was appropriate.

The first phase of lateral shrinkage of coke during coal carbonization has been shown to depend on the charge bulk density and coal composition, while the second phase is controlled by coking time and coking rate. The second phase of contraction was found to be almost the same for all the coals carbonized, while the total internal contraction was found to decrease with increasing charge bulk density [8]. The bulk density of 800kg/m^3 produced lateral contraction of about 13.5mm, while a charge density of 680kg/m^3 gave about 18mm [5]. The bulk density of 800kg/m^3 for the carbonization of Bellview coke falls within the range of 790 to 850kg/m^3 for carbonization at Krupp Mannesmam coke oven battery [9]. These results show that for improved coke pushing efficiency, the charge density of the Bellview coal blends may be reduced during industrial scale carbonization by the adjustment of its moisture content.

Coke density has also been shown to increase with depth in the oven, suggesting that the coking pressure depends on static load and the initial charge bulk density [10]. For a given coal blend, it has been shown that the average coking pressure determines the coke density which in turn determines the other physical properties such as coke hardness factor [10].The effects of greater static load on coal charge has been shown to lead to better coke strength for coals of the same bulk density ocarbonized in test coke ovens. These results indicate that the industrial scale carbonization of Bellview coals at the same bulk density or slightly lower may produce coke with micum strength better than M_{10} of 11.40% and 15.40% and M_{40} of 77.80% and 70.80%, for Bellview A and B respectively. It has been found that improved coke quality and other input materials play a key role in improving the performance of blast furnaces [11]. The M_{10} of SAIL steel plant cokes which range from 82.7% to 85.2% to far exceed the 77.8% and 70.80% determined respectively for Bellview coke A and B carbonized on pilot scale. These results show that the cold strength of the Bellview coke produced on pilot scale do not meet specifications for ironmaking. It is however expected that the cold strength of Bellview coke resulting from industrial scale carbonization are likely to be better due to higher coking pressure obtainable in industrial carbonization.

The abrasion resistance of 11.40% for Bellview coke A falls within the range of 9-13% for typical coke produced on industrial scale at Indian SAIL steel plant for ironmaking, while the 15.40% for the Bellview B coke falls outside this range [11]. For the German Sarr central coking plant, the M_{10} and M_{40} cold strength indices for coke taken from the conveyor towards the blast furnace are typically 5.5% and 76%, respectively. The M_{10} index of 11.40% and 15.40% for the Bellview coke showed that the coke have poorer abrasion resistance while the M_{40} of 77.80% for Bellview coke A showed that the coke has better resistance to fragmentation or in comparison to Saar coke [8]. The M_{40} of 79% to 80% for the Italian Trieste coke plant only slightly exceeds the 77.80%, for Bellview coke A, while the M_{10} index of 6% to 7% for the Trieste coke indicates its far greater resistance to abrasion in comparison to Bellview coke [12] .

The micum 10 and micum 40 values of 7% and 77% determined for coke produced in Taranto works showed that the coke has a better abrasion resistance than Bellview coke A while the latter higher M_{40} of 77.80% showed that it has a better resistance to fragmentation in comparison to Taranto coke [13]. The micum strength parameters determined for Bellview coke A thus compares favourably with cokes produced in other steel plants and the parameters could be used as a guide to select the coking improvement method required to improve the coke during industrial scale carbonization.

The pilot and industrial scale tests conducted in Spain showed that micum indices M_{10} and M_{40} for preheated charges were generally better than for wet charges. The preheating was done between 200°C to 230°C and the preheated charge was carbonized for 12.5hours to 14.5hours as against 18hours for wet charges [14]. For a particular charge, the M_{10} index improved from about 11% for wet charge to about 8% for preheated charge. However, the M_{40} for the preheated charge falls slightly below the M_{40} for the wet charge. These results thus strongly indicate the possibility of improving the micum strength of Bellview coke, particularly the M_{40} index by preheating treatment prior to industrial scale carbonization

The average flue temperature of 1330°C for Krupp Mannesmann coke oven battery exceeds the 1250 °C for the carbonization of Bellview coals. Also, the heating flue of 1340°C for the carbonization of coals in German Saar central coke oven plant exceeds the 1250°C for NMDC pilot coke oven [8]. The flue temperature of 1250°C however fall within the range of 1,225°C to 1229°C for Brazilian coke ovens and is similar to 1210°C, 1240°C, 1250°C and 1260°C in use at the Italian Taranto works [13,15]. The heating flue used at the NMDC coke oven carbonation thus meets the standard practice in some recognized steel industries and the strength properties of the coke produced are not likely to deviate from the expected values.

The coking time of 18 and 20 hours used for the carbonization of Bellview coals fall in the range 18 to 20 hours used for carbonization at the Taranto steel works coke oven battery [13]. The coking period of 18 and 20 hours also fall within the range of 18 to 24 hours for coal carbonization in Germany[16]. The coking periods of 18 and 20 hours however exceed the 14 hours used in an Indian coking plant [17]. The coking periods used for the pilot scale carbonization of Bellview coals thus fall within the range for standard coking practice in recognized steel industries and the results of micum drum test in the coke produced are thus likely to be reliable indices of Bellview coke strength.

4. Conclusions

On the basis of its volatile content, G-coking capacity and bulk density, the Bellview coals have been shown not to be susceptible to generation of excessively high internal pressure that may damage coke oven wall during carbonization. It has also been found that the greater static load in industrial coke oven may likely lead to the production of coke of better micum strength than obtained in pilot scale carbonization. The industrial scale carbonization of Bellview coals A and B may thus produce coke with resistance to abrasion and fragmentation that meet the maximum of 9% (M_{10}) and minimum of 78% M_{40}) required at the Nigerian Ajaokuta steel plant. In addition, coking improvement techniques such as preheating may be applied to eliminate the small deviations in M_{10} and $M4_0$ of +2.4%, and 0.2%, for Bellview coke A produced at pilot scale.

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