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EFFECTS OF PRE-HEATING ON THE MICUM STRENGTH OF COKE FROM A COAL BLEND INCLUDING 5% OF NON-CAKING NIGERIAN OKABA COAL

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Abstract

A coal blend consisting of 95% Australian Agro-Allied coal and 5% Nigerian non-caking Okaba coal was carbonized in a 250 kg capacity coke oven at a flue temperature of 1,250°C by normal wet and preheated charging for 18 and 15 hours, respectively. Screen distribution analysis and micum drum tests on the coke products gave M10 of 24.60% and 9.5% and M40 of 67% and 76.2%, for normal and preheated charge, respectively. These results showed that the coke produced from the preheated charge has a better resistance to abrasion (M10) and fragmentation (M40) and the micum indices obtained are similar to the micum characteristics of cokes produced in coke ovens in some other countries. Furthermore, the coke micum 10 and micum 40 strength are very close to the M10 and M40 specifications for coke to be used for blast furnace operations at the Ajaokuta Steel Plant, Nigeria.

Keywords: Coal; blend; flue; normal; preheated; mecum.

1. Introduction

A coal can be defined as a compact stratified mass of mummified plant debris, interspersed with smaller amounts of inorganic matter and covered with sedimentary rocks. The rank of a coal is the degree of change of chemical composition of the coal within the series of fossil fuel from peat to anthracite [1]. When coal is thermally decomposed in the absence of air volatiles are evolved. The process decomposes unstable molecules with the evolution of gaseous combustible substances. The product of the thermal decomposition of coal is coke which is the solid, coherent residue of the decomposition process. Bituminous grade coals suitable for straight carbonization are scarce worldwide. For example, as at 1977, only 15% coals from the Donetsky basin were coking [2].

In Nigeria, a proven coal reserve of about 257 million tons has been determined consisting of 74, 54, 107 and 22 million tons found in Okaba, Enugu, Ogboyoga and Lafia/Obi, respectively. All these deposits with the exception of Lafia-Obi coal are non-caking sub-bituminous coals. However, Lafia-Obi coal contains excessively high ash and sulphur contents of 26% and 2.3%, respectively. The deposit has also been found to have a faulty geological formation and would therefore be expensive to mine. The proximate analysis of Okaba coal and Lafia-Obi was reported by Adeleke et al [3]. Bench and pilot scale studies are normally conducted on coal blends prior to industrial scale cokemaking. Several coking techniques such as pre-heating, stamped charging and partial briquetting have been developed to improve the micum strength of coke from coal blends [4].

The aim of this research is to study the effects of preheating on the micum 10 (M10) and micum 40 (M40) indices of a coal blend consisting of 95% Australian Agro-Allied bituminous coal and 5% Nigerian non-caking Okaba coal carbonized in the pilot scale coke oven plant at the National Metallurgical Development Centre (NMDC), Jos. The pilot scale carbonization is to provide the required process parameters for industrial scale cokemaking at the Ajaokuta Steel Plant, Nigeria.

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2. Materials and methods

2.1. Materials

Samples of Agro-Allied and Okaba coals supplied in drums from Australia and Nigeria; respectively were used. The coal samples were air dried in the Coke oven plant, crushed with BB3 No 72414 jaw crusher and screened prior to mixing and carbonization.

2.2. Methods

The coal sample was carbonized in Deutsche Montan Technologie (DMT) 250 kg coke oven and the coke produced was subjected to screen distribution analysis and micum drum tests to determine the micum strength.

2.3. Pilot scale coal carbonization

2.3.1. Coal preparation

The mixture of Agro-allied and Okaba coals in 19:1 mass ratio (that is, 95% Agro-Allied and 5% Okaba) with the required grain size distribution was placed in Peter Kupper Aachen 12400 pre-heater mixer where it was thoroughly mixed for about 15 minutes before discharge for bulk density test. The procedure described was again repeated for another mixture of Agro-allied and Okaba coals in the same mass ratio but the sample was also further pre-heated at 150ºC in the pre-heater mixer.

2.3.2. Bulk density determination

The thoroughly mixed Agro-Allied sample was dropped into a steel chamber and the coal charge was leveled with the chamber brim. Water and diesel were added to obtain the required bulk density and moisture content of about 10%. The bulk density was calculated with equation 1:

$$Bulk\ density\ (\rho) = \frac{Weight\ of\ coal\ charge}{Volume\ of\ the\ chamber} \qquad (1)$$

The sample was prepared to obtain a bulk density of 805 kg/m^3. The procedure could not be repeated for the pre-heated blend at a much higher temperature of 150^{o}C.

2.3.3. Carbonization process

About 240 kg of wet Agro-Allied coal was dropped into the 250 kg capacity coke oven from a height of 5.2 m to the plant level for normal wet charging. The temperatures of the six heating flues were set at 1,250^{o}C and the sample was carbonized for 18 hours. The procedure was again repeated for the pre-heated charge mixture but with a carbonization period of 15 hours.

2.3.4. Coke quenching

The coke produced was pushed by an electric power driven mechanism into a quenching container where cooling was done for about 3 hours by water circulating around the coke in the container but not in direct contact with the coke.

2.3.5. Coke stabilization and screening

The quenched coke was stabilized by dropping it from a hopper placed at a height of about 5 m. Afterwards, the stabilized coke was screened through round hole sieve ranges of 0 – 10, 10 – 20, 20 – 40, 40- 60, 60 – 80 and + 80 mm in 411/400/Baujahr.1992 vibrating screening device.

2.3.6. Micum drum test

For micum test, 50 kg sample obtained from weights of selected fractions of +40-60, 60 – 80 and + 80 mm screens as defined by equation 2:

$$w_i = \frac{p_i}{W} x 50 \qquad (2)$$

i = 1, 2, 3 referring to the three +40 mm screen fractions obtained
Where:
w_i = weight of fraction i of the three +40 mm fractions required for micum test
p_i = weight % of fraction i of the three +40 mm fractions required in screen analysis
$W = \sum_i^3 p_i$ = summation of weight % of +40 mm fractions after screen analysis

was charged into MN 62108 Micum Drum where it was subjected to rotation for 4 minutes at 25 revolutions per minute. The coke product of this test was then screened again on the vibrating screen machine. From the results of the second screen distribution analysis with the 50 kg weight, the micum 10 (M10) and 40 (M40) were calculated from equations 3 and 4 [4].

$$M10 = w_j\, x 2 \quad (3)$$

Where:
w_j = weight of -10 mm fraction after the second screening test

$$M40 = W_t\, x 2 \quad (4)$$

Where: $W_t = \sum_k^3 w_k$ = summation of weight of the +40 mm fractions after the second screening.

3. Results and discussion

3.1. Results

The carbonization conditions used are presented in Table 1, while the results of screen distribution analysis are shown in Tables 2 and 3 and micum drum test in Table 4. Fig. 1 also shows the results of micum test in columns.

Table 1 Carbonization conditions for normal and pre-heated charges of 19:1 Agro-Allied and Okaba coal blends

Carbonization parameters	Normal wet charge	Pre-heated charge
Weight of charge (kg)	243	240
Weight of stabilized coke (kg)	144.45	163.50
Coke yield (%)	59.44	68.13
Flue temperature (^oC)	1.250	1.250
Charge Temperature (^oC)	1.130	1.200
Carbonization time (hours)	20	15

Table 2 Screen distribution analyses of the normal and pre-heated charge cokes

Sieve size (mm)	Normally charged coke weight (%)	Preheated charged coke weight (%)
-10	22.01	9.11
+10-20	3.87	1.87
+20-40	5.26	5.72
+40-60	18.55	22.42
+60-80	31.67	32.08
+80	18.62	28.81
Sieve size	Normally	Preheated charged

Table 3 Weight of +40 mm screen fractions required for micum test

Micum Indices	Agro-Allied coke normal charge	Agro-Allied coke preheated charge
Micum 10 (M10) %	24.60	9.50
Micum 40 (M40) %	67	76.20

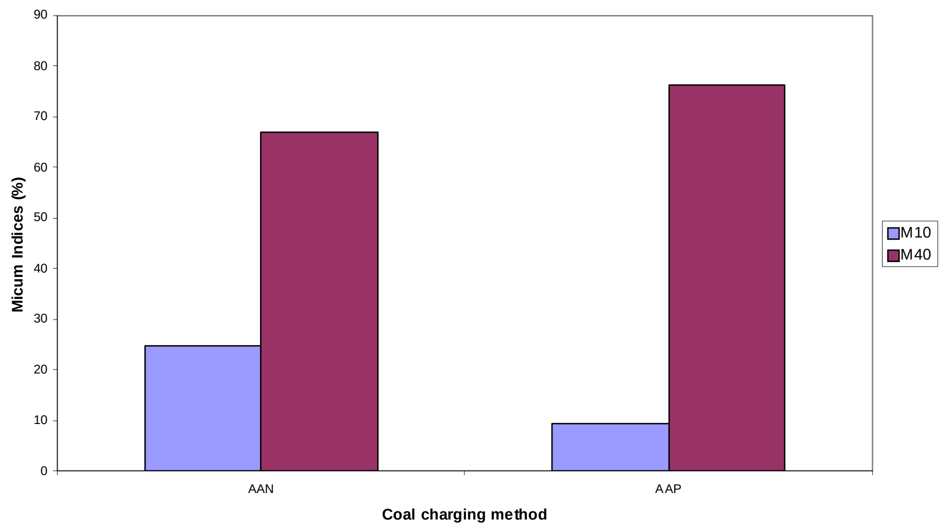

Fig. 1: Effects of coal charging technique on micum indices of resulting coke

3.2. Discussion

The heating flue temperature of 1,250°C used for the carbonization at the NMDC pilot coke oven was also used for coke production at the German Zentralkokerei Saar coke plant [5]. Similarly, the heating flue used at NMDC falls within the range of 1,210 and 1,260°C for the carbonization process in a Spanish coke plant [6]. However, the heating flue of 1,330°C used for cokemaking at the German Krupp Mannesmann steelworks exceeds the heating flue temperature used in NMDC by 80°C. These results show that the heating flue temperature used for cokemaking in NMDC is similar to those being used in recognized steel plants in other countries.

The coking period of 18 hours for the carbonization of the wet, normally charged blend only exceeds the 17.5 hours used for a wet charge at the German Krupp Mannesmann steelworks by 0.5 hours [7]. The heating duration of 18 hours for the wet charge in NMDC also agrees with 18 to 22 hours in use at the Italian Taranto works for wet charges [8]. The 15 hours used for the heating of the pre-heated charge only exceeds the upper limit of 14.5 in the range of 12.5 to 14.5 hours for the carbonization of pre-heated charges in a Spanish coke plant by 0.5 hours. These results show that the coking periods used for the carbonization both wet and pre-heated charges agree with the standard practice in other countries.

The micum 10 index (M10) of 24.60% determined for the coke obtained by normal charging of the blend far exceeds the 9.5% determined for the coke from pre-heated charge of the same blend. The very large difference of 15.1 units shows that the abrasion resistance of the coke from pre-heated charge is far greater than that of the coke from the normal wet charge. These results strongly indicate that pre-heating of coal blends greatly improves the abrasion resistance of the coke obtainable. The M10 of 24.60% determined for the coke from normal charging far exceeds the upper limit of 9% specified for coke to be used at the blast furnace in Ajaokuta for ironmaking by 15.6 units, while the M10 of 9.5% for coke produced from the pre-heated charge only exceeds the upper limit by 0.5 units [9]. These results show that the M10 index for the pre-heated charge almost satisfy the M10 requirement for Ajaokuta. Since the M10 of the normally charged blend deviate far above the permissible limit, the pre-heating treatment thus greatly improves the abrasion resistance of coke from a given blend.

The M10 of 9.5% determined for the coke from the pre-heated charge is lower than for all but one (i.e M10 of 11.5, 11.3, 10.8, 10.2, 10.0, 9.6 and 9.2) of the coke produced at the Indian SAIL coke oven plant [10]. It is also lower than 10% specified for typical coke in use in India [11]. The M10 of less than 7% determined for the coke produced at the German Zentralkokerei Saar coke plant is much lower than the 9.5% for the NMDC coke [5]. The M10 of 5.8, 6.2, 7.2 and 6.2 determined for typical coke from Redcar, Taranto, Schwelgern and Hoogovens steelworks, respectively [8]. These results show that the M10 of the coke from the pre-heated charge compares well with the M10 of coke produced in other countries. The M40 of 67% for the coke from the wet charge blend is lower than the 76.2% determined for coke from the pre-heated charge by 9.2 units. The M40 determined in both cases are lower than the lower limit of 78.8% specified for coke to be used in Ajaokuta by 11.8 and 2.6 units, respectively. These results show that the pre-heating treatment greatly raise the M40 index of the carbonized coal blend.

The M40 of 76.2% determined for the NMDC coke fall within the range of 75 to 80 % specified for coke in use in India [11]. The M40 index of 76.2% for the NMDC coke is lower than the M40 of above 82.4% determined for the cokes produced at the Indian SAIL plant [10]. However, the M40 of 72% to about 76.1% determined for coke produced at the German Zentralkokerei Saar coke plant is lower than the 76.2% for the NMDC coke. The M40 of above 84% determined for the coke from the UK Redcar coke plant exceeds the M40 for the NMDC coke. These results show that the NMDC coke with the M40 of 76.2 is similar to coke in use in the blast furnace in some other steelworks such as the German Zentralkokerei Saar steelworks. However, the micum strength of the coke needs to be upgraded when compared with coke in use in some other plants.

4. Conclusions

This study shows that preheating coking technique significantly improves the micum strength of coke obtained from the carbonization of a coal blend including 5% non-caking Nigerian Okaba coal. The M10 and M40 of 9.5% and 76.2% obtained for the coke from the pre-heated charge is similar to the coke strength of coke produced in some other plants and these values are very close to the micum strength specifications for coke recommended for use at the Ajaokuta steelworks in Nigeria.

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