Studies on the Gieseler Plastometry Parameters of the American Pittson Coal for Metallurgical Cokemaking at the Ajaokuta Steel Plant, Nigeria

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ABSTRACT

The Gieseler plastometric characterization of the American Pittson coal gave maximum fluidity, temperature range, Gieseler ratio 1(A1), Gieseler ratio 2(A2) of 2218 ddpm, 0.20, 4.13 respectively. The free swelling index analysis and determination for volatile matter content gave 7% and 27.15%, respectively. These results show that the Pittson coal is a prime coking coal of International Standard Organization (ISO) code 432 or 433, with good plastic fluidity property that may incorporate appreciable amounts of the low rank, non-plastic coals such as the Nigerian Enugu and Okaba in blends for metallurgical cokemaking. The wide temperature range for the coal also indicates that a wide range of medium grade coals with temperature ranges overlapping that of Pittson may be incorporated with it in cokeable blends for metallurgical cokemaking.

(Keywords: coal, coking, fluidity, cokemaking, coke)

INTRODUCTION

Coal is 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 fuels ranging from the least mature peat to the most mature anthracite (Francis and Peters, 1980).

When a bituminous coals is heated, it undergoes plastic transformation. At high temperatures, the coal will swell and be decomposed to a number of complex compounds with the evolution of various gaseous and condensing substances and at a definite temperature, the mass of coal becomes plastic due to the melting of low-melting point constituents called bitumen and their distribution between the non-melting components. With further increases of temperature, the plastic mass becomes non-plastic.

The coals' plastic behavior described results in the formation of coke, a solid residue having properties suitable for blast furnace iron-making. Metallurgical coke has a high mechanical strength and abrasion resistance to withstand abrading forces when a column of smelted charge gradually descends in a blast furnace (Krivandin and Markov, 1980). Free swelling index, Gieseler plastometer, and dilatometer are used to monitor the plastic behavior of coals (Gibson, 1982). The swelling ability of a coal on heating as indicated in a crucible swelling test is an important parameter in the International Standard Organization (ISO) classification of coals for cokemaking.

The fraction of coal soluble in benzene and chloroform is termed the "coking principle" and is called bitumen. Pyrolysis transforms coal into fluid products either completely or partially. It is the appearance of these fluid products which causes softening and plasticity of bituminous coals. The disappearance of the fluid products, either by evaporation or thermal decomposition, leads to re-solidification (Gibson, 1980). The Ruhr dilatometer is used to measure the expansion and contraction of coals when heated. The Ruhr dilatometer, a modified form of Audibert-Arnu dilatometer, gives a coal's initial softening temperature (E), the temperature at maximum contraction, the maximum contraction temperature, maximum contraction percent (c), maximum dilatation temperature (V) and the maximum dilatation (d).

In Gieseler characterization of coals, the softening temperature, temperature of maximum fluidity, maximum fluidity, and temperature range are determined. The mechanical strength of coke produced from the carbonization of bituminous coal is usually indicated by micum drum test which gives the M10 and M40 indices that show the coke resistance to abrasion and fragmentation, respectively. The aim of this research is to study the Gieseler plastometry parameters of the imported American Pittson coking coal and predict the coal suitability for straight carbonization or co-carbonization with low grade coals such as the Nigerian Enugu and Okaba coals in metallurgical coke production at the Ajaokuta steel plant, Nigeria.

MATERIALS AND METHODS

Materials

Samples of the American Pittson coking coal.

Methods

The free swelling index, volatile matter and Gieseler plastometeric parameters were determined. The samples were ground to pass 250 microns for both free swelling index and volatile matter tests and 425 microns for Gieseler plastometry (Loison et al, 1989; Francis and Peters, 1980).

Free swelling Index

One gram of coal in a silica crucible was heated on the Bunsen flame for 7 minutes. The coke button obtained was then compared with standard profiles and the appropriate number determined.

Volatile matter

One gram of coal was placed in a standard silica crucible (with three drops of Benzene added) was heated in a muffle furnace at 900 ^{o}C for 7 minutes and then cooled in the desiccators. The loss in weight account for the volatile content of the coal.

Gieseler Plastometry

Gieseler plastometer consists essentially of a cylindrical capsule of approximately 21.4mm in diameter and 18.3mm in height. It has a stirrer which has one end tapered to a point for resting in a groove at the center of the capsule for frictionless rotation.

Four rabble arms are fitted at right angles to the tapered end of the stirrer such that these wholly lie inside the capsule when the apparatus is assembled. The other end of the stirrer is coupled to an electric motor to provide a constant torque to the axis of the stirrer. The speed of rotation is displayed on the printer console.

Five grams of the coal sample ground to pass 425 micron, were compressed by a 10g weight placed on the sample with the stirrer arms fully embedded. After assembling the apparatus, the sample was heated as programmed on the Gieseler programmer.

The stirrer was immobile at the start of the heating since the rabble arms were rigidly held by the compressed coal. The movement started when the coal softened and continued as long as the coal remained in the plastic state. The movement stopped when the coal re-solidified. The speed of rotation (in dial division per minute, ddpm) varies with the fluidity of the coals.

RESULTS AND DISCUSSION

Results

The analysis results for free swelling index, volatile matter and Gieseler plastometry are presented in Table 1.

Table 1: Gieseler Plastometric, Free swelling index and volatile parameters of Pittson coal

S/No	Parameters	Value
1.	Free swelling index	7
2.	Volatile matter(daf) %	27.15
3	Gieseler Plastometry	
	Initial softening temperature(^{o}C)	390
	Resolidification temperature(^{o}C)	499
	Maximum fluidity temperature(^{o}C)(T)	450
	Maximum Fluidity(ddpm)(MF)	2218
	Temperature range(^{o}C)(TR)	109
	Gieseler Ratio 1(A1)	0.20
	Gieseler Ratio 2(A2)	4.13

Discussion

The free swelling index determined for Pittson falls within the range of 5.5 to 8.5 for typical Canadian coking coals and exceeds 6.5 for some French coking coals (Price et al, 1987; Podolak, 1987). The Pittson blend FSI exceeds 6.5 determined for the self-coking Australian Bulli coal (BHP, 1998) and is also greater than 4.5 specified for prime coking coal grades in the International standard Organization(ISO) coal classification (Panaitescu, 1991). The analysis results on Pittson coal caking behavior thus strongly indicates that the coal is of self-coking ISO grade.

The volatile matter determined for Pittson slightly exceeds 26.22% determined for the self-coking Bulli coal, but lower than 24.01% for a typical prime coking Indian coal (BHP, 1998; Prasad, 1992). The volatile content of Pittson also slightly exceeds the

25% determined for typical blends for cokemaking at the German Krupp Mannesmann steelworks (Beckmann and Meyer, 1992). The free swelling and volatile content results show that Pittson coal belongs to the prime coking ISO category V_B with ISO codes 432 or 433 (Panaitescu, 1991) similar to coals for metallurgical cokemaking in India, Germany and France.

The maximum fluidity of 2,218 ddpm for Pittson blend far exceeds 1,000 ddpm for Bulli coal, but is lower than 27,000 ddpm obtained for Canadian Nova Scotian coking coals (BHP, 1998; Price and Grandsen, 1987). The maximum fluidity for Pittson is also far greater than 1.9 to 195 ddpm for western Canada coking coals (Price and Grandsen, 1987). The Chinese Wugong coal with 13,800 ddpm far exceeds Pittson's maximum fluidity and gave a very high dilatation of 246.1% typical of high grade coals. The results of Gieseler maximum fluidity on Pittson thus strongly indicate that Pittson coal has a good plastic property characteristic of coals for metallurgical grade coke production. The relatively high fluidity of the coal also suggests that it may incorporate reasonable amounts of non-plastic, low grade coals like Enugu and Okaba.

The temperature range of 109 C determined for Pittson exceeds 85 C determined for the self-coking Bulli coal (BHP, 1998). The large temperature range for Pittson shows that the coal is cokeable and may accommodate a wide range of lower grade coals whose temperature ranges overlap its own in blends for metallurgical cokemaking. The Gieseler ratios of $A_1$and $A_2$of 0.2 and 4.13 are only slightly lower than 0.3 and 5.41 respectively, determined for the prime coking Bulli coal (BHP, 1998).The similarity of the ratios A_1 and A_2 for Pittson and Bulli coals further strongly suggests that Pittson coal is prime coking.

CONCLUSION

The high free swelling index, large maximum fluidity and wide Gieseler temperature range determined for the Pitson coal strongly indicate that the coal is a self-coking coal of ISO code 432 or 433 that may incorporate appreciable amounts of low grade, non-plastic coals and weakly coking coals with temperature ranges overlapping its own. The Gieseler ratios deduced in this work from Gieseler parameters, also confirm the coal as prime coking and thus suitable for metallurgical cokemaking.

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