Pre-heating and partial briquetting technique for production of coke from binary blend of local coal and bitumen

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Abstract— **Formulation of binary blend of coal-bitumen by weight (blend design involving 10 % bitumen and 90 % of preheated coal samples at about 150 ^{o}C) was carried out. The blend was then partially briquetted to increase the bulk density. The feasibility of the blend for the metallurgical coke production was investigated by physico-chemical analysis which revealed that the coking properties of the blend had been improved: particularly the Simonis' Coking Index (SCI) in LMZ and SKJ which was 0.92 and 0.99. The partial briquetted blend was co-carbonized at high temperature (about 1100 ^{o}C) for 15 hours for the metallurgical coke. The calorific value and chemical analysis of the metallurgical coke produced were carried out and the result of SKJ coke found to be close to the acceptable range for use in a blast furnace. Furthermore, the fissuring and abrasion index of the metallurgical coke were evaluated, and only SKJ coke has promising results: Micum 10 (M10) = 26.87 % and M40 = 65.69 % that almost meet the specifications for blast furnace, particularly Ajaokuta Steel Company, Kogi state of Nigeria. The results of this study revealed that the use of bitumen as a bonding substance has upgraded the weakly coking coal to cokeable blend for metallurgical coke making.**

Index Terms— **binary blend, metallurgical coke, physico-chemical analysis, bitumen**

I. INTRODUCTION

1.1 Background Information

Current worldwide iron making capacity is dominated by blast furnace technology (BFT) even though the prime coking bituminous coals suitable for straight carbonization are scarce, accounting for about 5 % of the world's supply of coals [1]. In 2013, the BFT produced 1,164,612,000 (about 1.2 billion) tonnes of hot liquid iron (pig iron/blast furnace iron) from 38 countries, accounted for 95.18 % of the global production. And in comparison with the direct reduction technology (DRT), only 58,939,000 (58.9 million) tonnes of direct reduced-iron was produced representing 4.81 %, and this has been the trend over years [2]. The success of blast furnace iron making technology is mainly as a result of continuous amelioration or improvement in coke quality which is one of the main objectives of this study. The high cost of bituminous coals due to high demand and inadequate coking coal reserves [3] and the possible effect of importation (logistic and international politics); has given rise to coal blend design which has become important technique and a common practice in the steel industry all over the world. The technique seeks to make cokes from coals which hitherto had been considered unsuitable for coke making, because of some undesired chemical and coking properties. Rheological properties of coal, in conjunction with sulphur, mineral matter and ash contents are the main determining qualities (factors) for straight carbonization and blend coking technology for metallurgical coke production in iron and steel industry [4]. Some coals possessing some of the coking properties may be lacking in others, and even detrimental to the coke ovens. In the past coke-makers relied on medium-volatile bituminous coals [5] but due to their scarcity and high price, coking coals of this rank are typically used as a 'base' in blends, to which coals of different rank and chemical properties are added, such that the overall blend achieves the required coke quality [6]. Co-carbonization is another process that involves the use of coking addictive such as bitumen, pitch or tar with coal to produce high-strength metallurgical coke for the blast furnace process [1], [7]. And raw material basis of coke (the most important chemical feedstock) industry is extended in metallurgy and consequently, low rate of coke consumption, high productivity and a cheaper production of hot metal are achieved [8]. For these reasons, the interaction of such additives with coal and their influence on coke quality is of growing interest [9], [10]. In fact research in coal blend formulation would be appreciated better if one considers the price of prime coking coal on the world market. A tone of prime coking coal sells for at least 220 USD [11].

The quality of coke can be improved to a great extent by the carbonizing conditions like the grain size of the coal charge; briquetted and stamped charging to increase the bulk density; addition of bonding substance and preheating technique employed for carbonization. Thermal treatment of coal by heating it at a low elevated temperature is termed preheating of coal. The process reduces the moisture content to 1 or 2 percent and then charging the coal at ambient temperature into the coke oven. Preheating of coal can be carried out at an elevated temperature of up to 300 ^{o}C in an essentially inert atmosphere so as not to affect the coking characteristics of the coal by softening, devolatization or oxidation. The pre-heating process allows the use of poor quality coal for coke-making, increases the bulk density of the coal charge and oven throughput which reduces energy consumption, and let to less thermal shock to the refractory brickwork when compared to wet charging; and hence improves the strength of the coke [12], [13, [14]. The major disadvantages of coal preheating are the operational problem of handling hot coal and high initial evolution of gases during charging process.

The aim of this paper is to improve the coking potentials of the weakly coking and non-coking coals by blending them with bitumen, and to assess the suitability of the coke produced from the co-carbonized blends for industrial application, particularly blast furnace use in iron and steel production.

II. Materials and Methods

2.1 Materials

The materials used for this study include five different coal samples collected from Garin Maiganga (GMG), Chikila (CHK), Lamza (LMZ), Shankodi-Jangwa (SKJ) and Afuzie (AFZ); all in Nigeria.

2.2 Methodology

2.2.1 Proximate Analysis

This involves the determination of moisture, ash and volatile matter content. These were conducted based on the American Standard for Testing and Materials [15] method of analysis - D3173, D3174 and D3175 respectively, while the fixed carbon content was obtained as the difference between 100 and the total summation of percentages of ash, volatile matter and moisture.

2.2.2 Composition and Partial Briquetting of Binary Blend

The pre-heating of the samples was carried out before blend formulation. In the preheating process, 9 kg of the coal sample was put in a retort, then placed into an oven and heated to a temperature of 150 ^{o}C for about 1 hour. The coal sample was then taken out and mixed with 1 kg of bitumen: 1 kg bitumen + 9 kg coal gives 10 % by weight bitumen binary blend. Thereafter, the blend formed was then briquetted in the machine and put into the metal retort, and then co-carbonized at higher temperature.

2.2.3 Physico-chemical Test of the Binary Blend

The physico-chemical analysis determines plastic properties of coal-bitumen blend. The standard plasticity tests were conducted based on the American Standard for Testing and Materials [15]: dilatation characteristic (D2014-90) was carried out on the binary blends.

2.2.4 Carbonization at Low and High Temperature [14]

The treated charge (pre-heated and briquetted) binary blends samples (25 kg), were put into a rectangular steel retort (with two openings for gaseous outlet at the top), and then placed into a furnace maintained at 100 ^{o}C. The furnace temperature was raised and maintained at 1100 ^{o}C, for metallurgical coke production termed coke A (c_A). The sample was carbonized for a period of 15 hours, after which the retort was taken out, cooled, opened and the resultant coke taken out for evaluation. For comparison, normal charging (non-treated charge) of the binary blend samples was also carried out to produce metallurgical coke B (c_B).

2.2.5 Chemical analysis and calorific value determination of the industrial coke

This involves the determination of moisture, ash and volatile matter content in the cokes produced. These were conducted based on the [15] method of analysis – D3173, D3174 and D3175 respectively, while the fixed carbon content was obtained as the difference between 100 and the total summation of percentages of ash, volatile matter and moisture.

2.2.6 Determination of the mechanical strength of the industrial coke (c_A and c_B)

This can be achieved through the following:

2.2.6.1 Drop shatter test [15] – D3030-72

Procedure: 500 g weight of coke was put into the container of the shatter or stabilization test facility, leveled and then dropped from a distance of 5 m in a conventional transit channel and fell on a steel plate into a collector. The coke mass was then separated into fractions on a screening machine with round holes according to sizes less than 10 mm (-10) to above 80 mm (+80), in preparation for the micum test.

2.2.6.2 Micum drum test [15] – D3402-81

Procedure: 50 g coke size of +80 (complemented with the next range of size) was placed in the micum drum and rotated at 100 revolutions for 1 minute, after which the coke sample was discharge into a collector. It was then screened, separated and weighed. The fraction of -10 multiply by 2 gives the M10, while the fraction such as +40 -60, +60 -80 and +80 were summed up together and multiply by 2 to give the M40.

III. Results and Discusion

3.1 Coking Potentials of the coals

The results obtained from the proximate analysis and of the Lamza (LMZ), Chikila (CHK) and Afuzie (AFZ), Garin Maiganga coal samples are shown in Table 1. The moisture contents range from 2.34 to 6.41 %, with CHK sample having the highest moisture content value and AFZ coal sample had the least. The GMG and LMZ coal sample had 6.17 and 3.37 % of the moisture content, respectively. Generally, moisture content values decreased in the order: CHK > GMG > LMZ > AFZ, which inversely correspond to their respective maturity level order. The lowest ash content of 6.22 % was observed in GMG. LMZ coal sample recorded the highest ash content of 12.67 %, while CHK and AFZ coal samples have intermediate values of 10.28 and 9.41 %, respectively. All the ash contents fall within acceptable level for coke making [16]. CHK coal sample had the highest volatile matter (VM) of 44.13 % close to AFZ coal sample with 42.67 %, while LMZ coal sample had the lowest value of 36.34 %. GMG coal sample had volatile matter contents of 39.98 %. The VM contents indicated that all the coal samples are of sub-bituminous rank [17]. The fixed carbon which determines the heating value and coke yield of a coal are generally moderate and appears to be satisfactory, are as follows: GMG and LMZ coal sample had highest fixed carbon content of 47.63 and 47.62 % respectively, closely followed by AFZ coal sample with 45.56 %. CHK coal sample had the lowest fixed carbon value of 35.46 %.

Assessment of these coal samples parameters indicated that LMZ and AFZ have little coking potential [17], that make them suitable for blending with prime coking coal. They can be used in conventional or formed coking technology. The conventional coking technology that involves the use of additive to produce coke is part of this study. Prior investigation of the proximate and ultimate analysis of SKJ coal revealed that it is of bituminous rank with better coking properties than the other coals, with potentials for blend formulation with a coking coal, despite its high ash and sulphur [4]. The coking parameters of the other coal samples indicate that they are of the rank of sub-bituminous. Generally, the coking properties of these coal samples are similar and almost fall within the same range (Figure 1), and may all be suitable for the technological production of the coke.

Table i: *Results of proximate analysis of coal samples*

S/N	Coal Sample	Percent Moisture content	Percent Ash content	Percent Volatile matter content	Percent Fixed carbon content
1	LMZ	3.37 ±0.67	12.67 ±1.11	36.34 ±0.77	47.62 ±1.81

2	CHK	6.41 ±0.73	10.28 ±1.12	44.13 ±1.34	35.46 ±1.14
3	AFZ	2.34 ±1.25	9.41 ±0.75	42.69 ±1.18	45.56 ±1.18
4	GMG	6.17 ±1.34	6.22 ±0.97	39.98 ±1.16	47.63 ±1.33

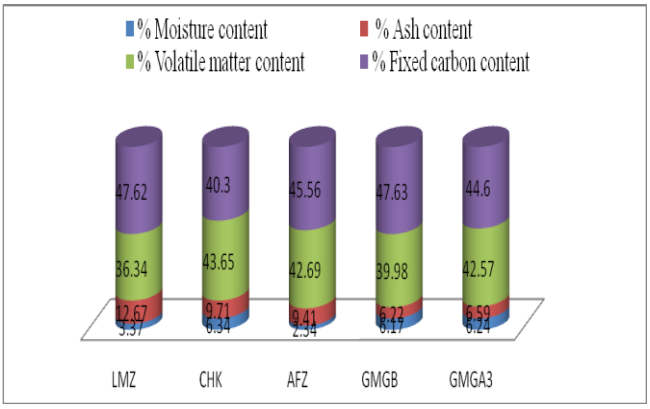

Fig. i: Coking potential of coal samples

3.2 Dilatometric Properties of the Binary Blend

The results obtained from the Ruhr dilatometric analysis of the coal-bitumen blends are shown in Table 2. The dilatometric characteristic values like maximum dilatation and the dilatation temperature of CHK, GMG and AFZ blends were not detected, and so zero G-value (coking coefficient) was recorded. SKJ blend recorded a softening temperature of 350 ^{o}C, attained maximum contraction of 20.5 % at a temperature of 415 ^{o}C and has the highest maximum dilatation of 21.2 % at a temperature of 455 ^{o}C, with coking coefficient of 0.99 which is promising for coke production. The LMZ blend also has appreciable critical dilatometric properties, dilatation of 11. 2 %, and the coking coefficient or Simonis' G-value of 0.92.

At high temperature, bituminous coking coal co-exhibits dilatomeric and rheological plastic properties, and after about 15 hours, produces a coherent residue called coke of which the strength depends on the coking properties of the coal [18]. Dilatometry is a physico-chemical test that further confirms the cokability of the binary blend by the coking coefficient. The Simoni's coking index for medium and strongly coking coal as well as coal blend lies between the range of 0.95 – 1.15 [16]. Among the blend samples SKJ and LMZ have appreciable dilatometric properties: Simoni's coking index of 0.99 and 0.92 respectively, falling within the range indicating that it is weakly/medium coking [19]. Among the coal samples, it was observed that only SKJ and LMZ binary blend dilated even though all the blend samples exhibited various contraction levels during the plasticity test. The variation in dilatometric properties such as percentage dilatation, maximum contraction temperature, percentage contraction, and so forth is as of differences in mineral composition and content [20]. The percentage dilatation of this test is used in the International Standard Organization (ISO) chart for coal classification.

Table ii: Ruhr dilatometric results of the binary blend (bitumen-coal blend ratio of 1:9).

S/N	Analytical parameters of the coal samples	Characteristic values of:				
		LMZ coal	CHK coal	AFZ coal	GMG coal	SKJ coal
1	Softening temperature (^{o}C)	360 ±2.74	355 ±2.89	345 ±3.64	358 ±4.14	350 ±3.25
2	Maximum contraction temperature (^{o}C)	412 ±4.05	392 ±2.95	382 ±3.98	396 ±2.25	415 ±3.42
3	Maximum dilatation temperature (^{o}C)	463 ±3.84	-	-	-	455 ±4.14
4	Maximum contraction (%)	8.5 ±2.01	-4 ±2.12	3 ±1.72	5 ±1.81	20.5 ±1.26
5	Maximum dilatation (%)	11.2 ±1.56	-	-	-	21.2 ±1.86
6	G-value	0.92 ±0.02	Nd	Nd	Nd	0.99 ±0.01

NB: Nd = not determined

3.3 Chemical properties of the industrial (metallurgical) coke A

The result of Chemical assessment (proximate analysis) and calorific value of the industrial (metallurgical) coke is shown in Table 3. The moisture contents of the cokes fall within 0.32 and 1.33 %, and all values are within the range metallurgical use. The volatile matter contents of the cokes range from 6.51 – 24.92 %, all falling above the maximum limit for use as metallurgical coke. Among the cokes, the GMG blend coke has the least ash content of 6.05 % which falls within the required level, while the SKJ has the highest ash content of 14.26 % above the maximum level for metallurgical application. The cokes had appreciable fixed carbon ranging from 65.70 – 78.61 %, with good heating values above the minimum of value of 5,510 cal/g for energy source, which fall between 6,077.09 – 7,518.20 cal/g. The sulphur contents are close to each other with the least amount of 0.39%, observed in AFZ coke and the highest value of 1.29 % in SKJ coke slightly above the maximum recommended level of 1.2 % [17].

The chemical composition (properties) of coke is generally assessed like coal in terms of moisture, ash (e.g. alkalis), volatile matter, sulphur and phosphorus contents which are impurities; and in addition, physical strength which is measured by its impact hardness and resistance to abrasion. These impurities present in coke, affect its performance in the blast furnace by decreasing its role as a fuel in terms of amounts of carbon available for direct and indirect reduction roles and also its role as a permeable support [21]. Their levels are to be kept as low as possible.

Amongst the chemical properties, sulphur and ash (content and chemistry) are undesirous because certain level of them results into decrease coke productivity in the blast furnace. The ash in coke is of great significance in metallurgy: the coke ash is a non-productive part of coke which influences slag volume and composition as well as low efficiency of the blast furnace. Values higher than 10 weight % can be

satisfactory but only if the ash chemistry is acceptable [21]. The ash and sulfur content are linearly dependent on the coal used for production. Coke with less ash and sulfur content is highly priced on the market. The chemical quality of coke is a direct reflection of the quality of the feed coals. Essentially all inorganic elements remain in the coke; hence the ash content of the coke is directly proportional to the ash or mineral content of the coal. Coal contains a variety of minerals in varying proportions that, when the coal is burned, are transformed into ash. The amount and nature of the ash and its behaviour at high temperatures affect the design and type of ash-handling system employed in coal-utilization plants [22]. One of the important elements in coke is silica content, which must be low and not exceed 64 %. Amongst the cokes, only SKJ coke has ash content of 14.26 % slightly above the 13 % maximum for metallurgical use [17].

Sulphur content in coke has a considerable effect in metallurgy: it gives rise to brittleness and corrosion because some of the sulphur in coke passes into the matrices of the iron. It is therefore a very important quality index, which can be regulated easily only by the choice of coal(s) for carbonization [23], [24]; and this justified the use of these coal samples (particularly LMZ, CHK, AFZ and GMG) for the production of the metallurgical coke. The formation of di- and tri- sulphur oxide during high-temperature treatment of coal or coke gives rise to sulphuric acid that causes industrial fume [23]. It is possible to desulphurise the coal, but it's a relatively costly operation. The sulphur content of the coke is therefore an important characteristic and it should not exceed 1.2 % for most application [17]. The sulphur content of the metallurgical cokes produced in this project is generally low within the acceptable limit for most application, except SKJ coke with 1.29 %, slightly above the required level for use [17]. The high values recorded in the SKJ coke correspond to the high value of the sulphur in the parent coal SKJ coal with 1.63 % [4].

One of the disturbing factors about coke as a fuel is the chemical parameter such as moisture content, because it reduces the heating value (calorific value) of the metallurgical coke. It is an important parameter in commercial transaction and in control of blast furnace operation. Blast furnace operators generally require a practically dry coke. Moisture content is a direct consequence of the coke-quenching process with some dependence on size. The water content in coke is practically zero at the end of the coking process, and if water quenched for use in the blast furnace, the porous structure of the coke absorbs some water. The water particles may adhere to the lump of coke and falsifies the result of sieve analysis, essentially the M10 index. In modern coke plants, an advanced method of dry-coke quenching uses air for cooling, as practice in Japan and Russia [25]. Coke moisture content ranges from 1– 6 weight % maximum, and common values are in the range 3 – 4 weight % [21]. All the cokes produced in this work have satisfactory moisture contents suitable for intended area of applications. This could be due to method applied in quenching the products, which was done by leaving it to cool on its own as it is left in furnace overnight.

Volatile matter does not form part of the coke. It is usually part of tar and gaseous component such as hydrocarbons, methane, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen that are evolved during carbonization. According to [21], volatile matter contents cause operational problems in the cleaning of blast furnace gas. The volatile matter content of coke, suitable for metallurgical use should not exceed 1.5 % [17]. It is widely speculated that high volatile matter in the cokes produced may be as a result of incomplete carbonization of the charge sample. And according to [26], increasing pyrolysis temperature correspondingly increases the volatile yield whilst increasing the pyrolysis pressure (of which strongly dependent on coal type and pyrolysis temperature) generally decreases the volatile yield. In this work, all cokes produced have values of volatile matter far above the maximum level requirement for use, with the exception of SKJ coke which has 6.51 % little far above the limit for metallurgical use [17]. The high values of the volatile matter content observed in other cokes produced may be due to quality of the parent coal which can be confirmed in further study.

Table iii: Chemical analysis and calorific value of the industrial coke

S/N	Sample detail	Moisture content (%)	Volatile matter content (%)	Ash content (%)	Fixed carbon content (%)	Sulphur content (%)	Calorific value (cal/g)
1	LMZ $_{coke}$	0.32±0.65	16.74±3.25	8.98±1.45	73.96±2.55	0.49±0.41	6,409.49±12.05
2	CHK $_{coke}$	1.33±1.01	24.92±2.57	8.05±2.88	65.70±1.96	0.46±0.16	6,077.09 ±8.95
3	GMG $_{coke}$	1.08±1.15	23.98±3.28	5.75±2.05	69.19±3.02	0.54±0.12	6,469.45±13.11
4	AFZ $_{coke}$	1.31±0.45	19.14±3.75	6.75±2.01	72.80±1.97	0.39±0.53	7, 202.05 ±9.98
5	SKJ $_{coke}$	0.62±0.80	6.51±2.69	14.26±2.93	78.61±2.66	1.29±0.33	7,518.20±10.75

3.4 Mechanical properties of the metallurgical coke A (c_A)

The results of the mechanical strength analysis of the metallurgical cokes are presented in Table 4. For the various cokes tested, the CHK coke has the least quality with abrasion index (M10) of 47.45 %, closely followed by GMG coke with M10 value of 39.75 %. The lower the M10 value the better the coke quality but the higher the M40 value the better the quality. The AFZ and LMZ coke recorded M10 = 31.06 %, M40 = 39.98 % and M10 = 29.85 % and M40 = 43.97 % respectively. Only SKJ coke had the highest strength of M10 = 26.87 % and M40 = 65.69 % which is close to metallurgical coke required for blast furnace.

As coke plays an essential role in maintaining the permeability of the blast furnace as well as the chemical transformation of the raw material (coal), much importance has always been attached to the most significant attributes of coke (physical and chemical properties) which are its mechanical strength (stability), lump size, shape, chemical composition as well as chemical reactivity and uniform

combustibility [27]. Thus coke of high strength can withstand the mechanical impact of handling before charging and during descending process in the blast furnace. Coke strength involves fissuring and breakage along the boundaries of, or sometimes through, both macroscopic and microscopic coke components, with porosity being a dominant factor. To this end, various techniques have been developed to improve the bonding strength between the textural components of the coke such as briquetting, pre-heating, stamping of the coal or blend before carbonization [28]. The size of coke is a dominant factor in determining the permeability of the bed of blast furnace. The mechanical characteristics of good coke that is generally accepted for blast furnace operation is in the size range of around 30 – 60 mm [17]. In metallurgy, coke size uniformity is also important, but the sizes of cokes produced in this work vary, comprises mostly of small pieces. Finely crushed coke pieces must not be allowed into the blast furnace because they may impede the flow of gas within the system. Generally, the size of the stabilized coke in this work is far below the lower limit. Indeed, this is (size) a reflection of the mechanical strength of the coke produced.

The most important physical characteristics are the Micum10 and Micum40 test indexes, which convey the strength of coke during transportation into the blast furnaces as well as the resistance to crumbling. The micum test provide two pieces of information, as it characterizes the tendency of the coke to fissure (M40) as well as its cohesiveness or abrasiveness (M10). Thus a good metallurgical coke should have high resistance to degradation under chemical and thermal environment in order to withstand the weakening reactions with carbon dioxide and alkali, abrasion and thermal shock in the blast furnace [21]. In this work, cokes A (c_A) were produced from the pre-heated and briquetted (treated) binary blend samples. It was noticed that the mechanical properties such as abrasion and fissuring resistance of the c_A tends to increase linearly with the level of the binary blend fluidity as well as the Simoni's G-value: there is a positive correlation between the maximum fluidity and fissuring index of the cokes produced (Figure 2) . For instance, the lower the value of the abrasion index as in LMZ and SKJ coke with 29.85 and 26.87 % respectively, the better the abrasion resistance; while the higher the fissuring index as in the SKJ coke with 65.69 %, the better the fragmentation resistance (Figure 3). Amongst the cokes produced in this work, only SKJ coke has appreciable coke strength that is closer to the metallurgical requirement, especially for Ajaokuta Steel Plant (ASP) blast furnace use [17].

Table iv: Determination of the mechanical strength of the industrial coke (c_A)

S/N	Sample Detail	Abrasion index (M10)	Fissuring index (M40)
1	LMZ coke	29.85±2.35	43.97±3.65
2	CHK coke	47.45±3.43	Nd
3	GMG coke	39.75±2.77	Nd
4	AFZ coke	31.06±2.48	39.98±2.83
5	SKJ coke	26.87±3.05	65.69±3.15

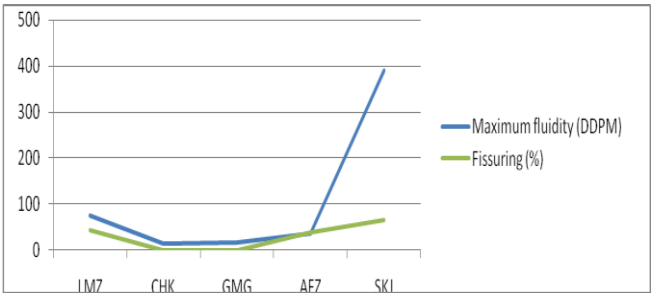

Figure ii: Positive correlation between maximum fluidity and fissuring index of the cokes

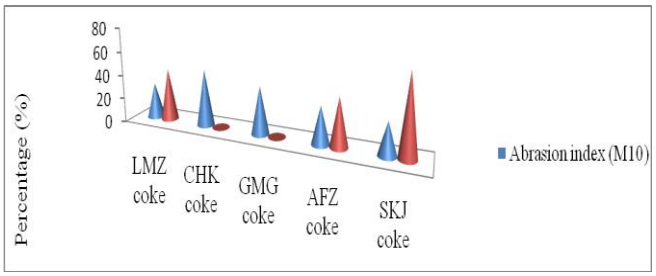

Figure iii: Mechanical strength of the metallurgical coke (c_A)

3.5 Mechanical properties of the metallurgical coke B (c_B)

The results of the mechanical strength analysis of the metallurgical cokes (c_B) are presented in Table 5. The mechanical properties of these cokes were generally very poor with the abrasion index (M10) of CHK = 51.53 %, GMG = 45.35 %, AFZ = 41. 65 %, LMZ = 37.08 % and SKJ = 30.81 %. The lower the M10 value the better the coke quality but the higher the M40 value, the better the quality. For the M40, only LMZ and SKJ coke recorded results of 22.85 % and 41.74 % respectively which are far below metallurgical coke required for blast furnace.

For comparison, the conventional coking technology was employed in which the binary blend samples were charged into the furnace without treatment and cokes B (c_B) were produced. The mechanical properties the c_B were general very poor, far below metallurgical requirement.

Table v: *Determination of the mechanical strength of the industrial coke (c_B)*

S/N	Sample Detail	Abrasion index (M10) %	Fissuring index (M40) %
1	LMZ coke	37.08±1.95	22.85 ±1.78
2	CHK coke	51.53±1.77	Nd
3	GMG coke	45.35±1.98	Nd
4	AFZ coke	41.65±2.33	Nd
5	SKJ coke	30.81±1.79	41.74 ±2.06

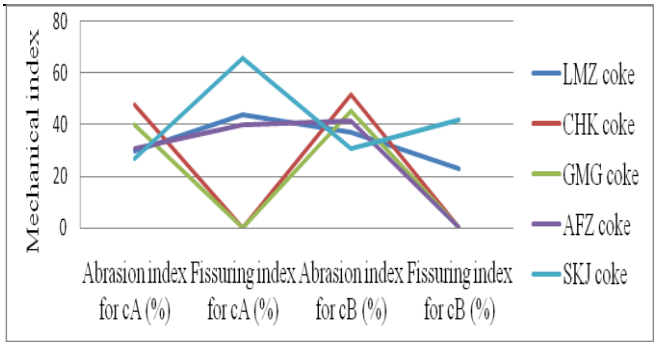

Figure iv: Comparison of mechanical properties between coke A and coke B produced

This development portrayed good indices that the pre-heating and briquetting technique appeared to yield moderate/reasonable prospect of coke quality than the conventional (normal) coking (Figure 4). This strongly confirms that pre-carbonization or coking techniques improve coke quality [28, 29]. In general, the mechanical investigation results of both coke A and B, indicated that the quality of parent coal plays an important role in the blend formulation and charge treatment.

IV. CONCLUSION

The use of bitumen, and in addition the briquetting and the pre-heating techniques employed greatly influenced the coking potentials of the coal samples and produce cokes of quality that may proportionally depend on the chemistry/quality of the parent coal: SKJ binary blend with the best dilatometric properties produced coke (coke A) with mechanical properties that almost meet the blast furnace requirement of ASP for the production of iron.

The physical and chemical properties that influence the coke behaviour and reaction during heat treatment in a boiler are appreciable in SKJ blend-coke and little bit of LMZ coke.

During the blend formulation, a strong interaction was observed between the coal and bitumen, and so optical microscopy of the blend should be carried out in further study to determine whether it was isotropic or anisotropic interaction.

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