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Effect of Weathering on Coal Quality

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Abstract : During transportation and stockpiling, coal is in contact with air for periods of time that may exceed 6 months. During this time, reaction with oxygen in the presence of water, sunlight and possibly elevated temperatures may take place. The resulting weathered coal suffers some alteration in its technological properties

This paper describes what is weathering with reference to coking coal, why it is important to understand the coal weathering. In this paper effect of weathering on coal quality discussed. Two types of Indian coal were kept for a period of 2 months and different property of coal monitored at different intervals. In this paper a new method like change in pH tried for Indian coal.

Key words: Coal, Weathering, Slurry pH, coal quality, FSI, coke quality

1. Introduction:

Coal is a compact stratified metamorphosed mass of varying maturity originated mostly from plant materials. It is a complex organic macromolecular substance. Coal can be classified as coking or non coking depending on its behavior when heated to a temperature of about 700 ^{O}C to 1000^{O}C in absence of air. If coal softens, devolatilises and solidifies into porous hard solid coke it, is classified as coking or caking coal. If the residue left on heating in absence of air be weakly coherent or powdery mass then it termed as non coking.

The process of heating of prepared coking coal charge or blend of coking coals in absence of air to a temperature of ~700 OC or ~1000OC to pass through different stages such as softening, swelling and resolidification into coherent cellular mass called coke is known as carbonization. Coke is one of the important raw materials for the Blast Furnace. Aprrox 75% of the furnace is filled with coke. Coke plays very important role in Blast furnace like physical, chemical and thermal. It acts as fuel, generate coke oven gas which acts as reducing agent and supports the overlaying burden in the furnace. Therefore properties of coke (hot and cold strength) are varying important for efficient operation of Blast furnace.

The properties of weathered coal have adverse effect on coke properties. Weathering of coal start as coal is mined and it will continue till it is charged in coke oven to produce coke. In mines coal exists in a water-saturated, oxygen-free environment, any disturbance of this environment such as a change in the temperature, moisture content or oxygen partial pressure, result in change of chemical properties, physical stability. This dynamic behavior of coal is termed ‘weathering’ and includes the aerial oxidation of the organic and mineral matter (chemical weathering), the microbial oxidation of pyrite (biological weathering) and changes in the moisture content that result in particle size degradation (physical weathering).

During transportation and stockpiling, coal is in contact with air for periods of time that may exceed 6 months. During this time, reaction with oxygen in the presence of water, sunlight and possibly elevated temperatures may take place. The resulting weathered coal suffers some alteration in its technological properties and size degradation. Different coal follows different trends during weathering.

The weathered coal affect its beneficiation process as due to oxidation coal surface property get changed and coal surface become more hydrophilic. These results in difficulty in separation from mineral matter and beneficiation efficiency of floatation, agglomeration and flocculation process get reduced.

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Weathering results in a vary rapid deterioration in fluidity and reduction in plastic range. This may be due to formation of highly cross-linked macro molecular structure which will not easily melt and flow during heating.

Oxidation also reduces the calorific value of coals as indicated below:

Coal Rank	% increase in Oxygen	kcal loss/kg
Low rank coal	1	106
High rank coal	1	133

In respect to carbonization process, the important coke making properties of coal viz FSI, Fluidity get decreased and it result in poor coke quality, so determination of degree of weathering is important. In addition to above the other operational problems are bulk density control, carbon deposit are leading to oven damage ,poor coke strength ,coke handling problem, reduced coke yield.

In general coke strength after reaction (CSR) reduced by 1 unit for each month storage. Increase in 1% of oxygen destroys caking properties of prime coking coal.

2. Material and Method

In this study 2 types of coal Prime and medium coking coal used in one of the SAIL plants collected. Collected coal sample first screened through (12 mm) screen and sample which passes through 12 mm screen as shown in figure (1) then stored in open tray and kept at Research and Control Lab of Bhllai Steel Plant for a period of 2 months. The figure (2) shows the sample stored to monitor the coal weathering. Evaluation of weathering is planned to be carried out at an interval of 20 days. It means after fixed interval a representative sample withdrawn for study the effect of weathering.

Figure 1: Screening of coal

Figure 2: Storage of coal

2.1Methods to Monitor Coal Weathering

As we know that coal is heterogeneous in nature, and from literature it is now known that weathering of coal strongly depends on coal rank and seam, so it is very difficult to define reliable standard value for degree of oxidation.

Yongseung yun et.al [1] found that most of the method for determining of weathering provides relative values; they are useful only when starting value is known. Many empirical methods compare fresh coal to oxidized coal, with the assumption that in-situ coal seam is not subjected to weathering; while actual this is not the case. In past many attempts have been made to measure the coal weathering by following methods

- Determine the oxygen content by oxidative, reductive, or pyrolytic methods
- Change in caking properties of coal (swelling prop of coal)
- Alkali extraction test
- Fourier Transform Infrared Spectroscopy (FTIR, PA-FTIR, TG-FTIR)

- Petrography
- Thermal analysis methods, e.g., thermogravimetry (TG)
- The Zeta potential of coal particle suspensions in H20
- Coal slurry pH measurement
- Froth flotation

In spite of above, methods there are some more methods but till date no single method is self sufficient to monitor coal weathering.

Yongseung Yun et.al [1] found that simple pH determination of rehydrated coal slurry was a successful technique to monitor coal weathering. But for Indian coal this type of study has not been done yet. Therefore in our study we have tried to use change in ph of coal slurry as newer method to monitor coal weathering. In addition to this proximate analysis and Free Swelling Index of the samples also determined.

- **Proximate Analysis**

Proximate analysis for Ash & VM: From representative sample, TA sample (-72 mesh) has been prepared for the proximate analysis. Proximate analysis will be done as per (IS1350 Part I).

- **Free Swelling Index (FSI)**

This is the widely used test; carried out to estimate coking power of coals. FSI test can be carried out with same TA sample which is prepared for proximate analysis. Test will be conducted as per IS1353.

- **Coal Slurry pH Measurement**

In this test 2 gm (-60 mesh coal) and 20 ml distilled water has been heated to 150 C for two hrs. Then it is cooled by tap water indirectly. Coal slurry will be transferred to beaker and its pH has been determined by respective probes.

3. Results and Discussion

PCC and MCC coal of size (-12) mm stored in Lab to monitor the coal weathering effects. Representative sample were withdrawn from tray at a fixed interval. These samples are reduced by coning and quartering then grinded in ball mill. Grinded sample were screened through 72 and 60 mesh. Sample which pass through 60 mesh were used for pH measurement while (-72) sample used for proximate and FSI analysis.

The proximate analysis involves determination of moisture, VM, ASH and fixed carbon using procedure stated in 2.1. Pisupati et.al. (2) also does not found any changes in ASH with time. In case of VM some authors found increase in VM for oxidized coal compared to fresh coal, while some reported decreasing trends. This is in agreement with may be due to fact that changes in VM depends on sensitivity of aliphatic and alicyclic to oxidation ,and how these groups are combine [3], and it differs from coal to coal.

Table 1 shows ASH ,VM and FSI value measured at different time for Prime coking coal (PCC). The changes in values of ASH, VM and FSI with time for Medium coking coal shown in Table 2

Table 1: Change in FSI, ASH and Volatile matter (VM) with time for PCC Coal

Date	FSI	ASH	VM
12.08.13	3	20.7	19.4
3.09.13	3	20.7	19
19.09.13	2	20.2	18.7
10.10.13	1.5	20	18.6

Table 2: Change in FSI, ASH and Volatile matter (VM) with time for MCC Coal

Date	FSI	ASH	VM
12.08.13	1.5	23.6	24.2
3.09.13	1.5	23.4	24
19.09.13	1	23	23.5
10.10.13	1	23	23

In case PCC coal the value of ASH was almost constant for entire period. Volatile matter reduced from 19.4 to 18.6. While for MCC coal The value of ASH was almost constant for entire period. Volatile matter reduced from 24.2 to 23 as shown in table 1 and 2 respectively.

Free swelling index measured by as per above mentioned procedure. Most researchers found that FSI is poor indicator of weathering in initial stage of weathering compare to other empirical methods like Gieseler maximum fluidity. Larse et .al [4] suggested that loss of donatable hydrogen is responsible for loss in FSI while Iglesias et.al [5] correlated it with loss in alkyl group

For PCC coal FSI value for zero day sample i.e. the first day when sample kept for study was 3.0 and it reduced to value of 1.5 in a span of 2 months. In case of MCC coal FSI reduced from 1.5 to 1.0 during storage periods. Figure 3 shows changes in FSI with time for both coals

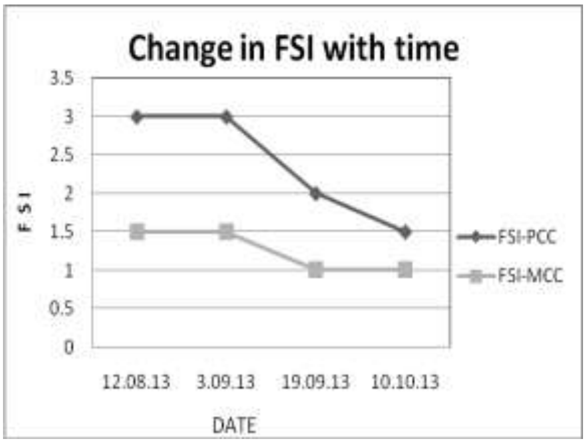

Figure3 Change in FSI with time for PCC and MCC C4oal

Gray et.al [6] suggests slurry pH as a technique to monitor coal weathering. They found that for low volatile bituminous coal pH changes from 7.1 to 5.5 .Hill et.al [7] use 0.01 % surfactant to increase wetting of coal. They observe change in pH and put effort to correlate it with loss in calorific value. H.S Valia et.al [8] suggested that the changes in pH value may be due to release of sulfur and acid produced during oxidation. It is also known that low rank coal produce more acidic group. Raja sen et.al [9] put major emphasis to use this method for Indian coal.

The ph measurement for both coal i.e. PCC and MCC coal were carried out as per above discussed procedure. Table 3 represents values for pH of PCC and MCC for PCC coal pH reduced from 6.1 to 5.82 while for MCC coal 6 to 5.76. This is in agreement with the fact that low rank coal produces more acidic groups. The change in pH with time for PCC and MCC Coal shown in figure 4.

Table 3: Change in pH with time for PCC and MCC Coal

Date	pH-D(PCC)	pH-K (MCC)
12.08.13	6.1	6
3.09.13	5.95	5.95
19.09.13	5.92	5.83
10.10.13	5.82	5.76

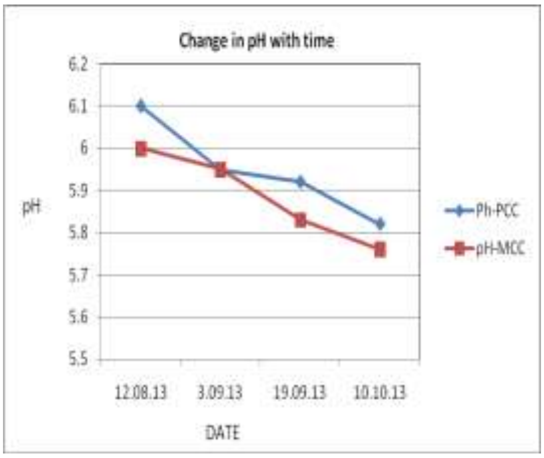

Figure 4: Change in pH with time for PCC and MCC Coal

4. Conclusions

The objective of above work was to find easiest method to monitor coal weathering for Indian coking coal i.e. PCC and MCC.

1. FSI measurement is a good indicator to monitor coal weathering. But it has practical limitation; it depends on visual observation of operator. FSI values are in the increment of 0.5 no value in between so for moderate degree of weathering it is not suitable.
2. In the work, no change in ASH value observed during 2 months storage periods. Volatile matter reduced by marginal amount. They are also not useful to monitor moderate coal weathering.
3. pH value appear to be a good indicator for moderate coal weathering. It does not depend on operator skill as values are measured by probes.

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