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Characterization of macerals in coal fines using image analysis technique

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ABSTRACT

Coal is an aggregate of heterogeneous substance consisting of various organic constituents so called macerals along with inorganic matter. These macerals have been broadly classified into three major maceral groups i.e. vitrinite, exinite (liptinite) and inertinite. Coal fines of size less than 0.5 mm, collected from Moonidih coal washery, was used in the present study. These coal fines were subjected to size analysis and sink-float analysis. The products obtained at different size and density fractions were mounted in resin + hardener mixture using standard sample preparation technique and polished. The polished samples were examined under microscope interfaced with image analyzer. Results indicate that size and density fractions have a significant influence on the changes in the maceral concentrations. The same has been discussed in terms of physical coal cleaning process.

Key words : *Macerals, Image analysis and Kelsey centrifugal jig.*

INTRODUCTION

Characterization of coal is considered to be one of the important steps that would provide great information in utilization point of view. Petrographic characterization of coal is extensively used in coke-making industry particularly to assess the reactivity of coals for combustion and liquefaction etc[1]. The petrographic technique is also finding application in solving problems concerning coal beneficiation.

Coal macerals can be defined as the microscopically recognizable organic constituents having no definite crystal structure and chemical composition. These macerals are generally classified into three major maceral groups and each group represents the maceral having ubiquitously similar properties in a coal of specific rank. Understanding the nature of coal in terms of macerals concentration has been well brought out by several workers[2-5].

Macerals characterization philosophy slowly changes from conventional cumbersome methods to more sophisticated and reliable procedures. Image analysis method is one such kind of procedures. It not only reveals significant amount of petrographic information but also facilitates in identifying and quantifying the macerals present in coals at much faster rate. A large number of investigators contributed towards the understanding of characterization of macerals in coals employing image-processing procedures. Riepe and Steller[6] described the characterization of coal and coal blends by automatic image analysis. Mukherjee et. al.[1] explained about the coal micrograph image understanding system. Banerjee et. al.[7] have tried to predict the ash content of coal using the image analysis technique. A more detailed image texture analysis based procedure to characterize and recognize coal macerals is given by Agus et. al.[5].

Several beneficiation techniques adopted for the concentration of macerals such as froth flotation process[8-12], magnetic techniques[13] and electrostatic separators[14]. Except froth flotation technique these studied have not gained wide acceptance due to economical factors. Reports are also available on gravitational separation of macerals using centrifugation techniques[15-16]. These centrifugal techniques are showing promising potential for the concentration of macerals because of their simplicity and ease in operation.

Very limited work has been carried out using image analysis technique for the maceral characterisation of Indian coal fines[1,7]. Further, maceral enrichment studies have not been carried out on Indian coal fines using enhanced gravity concentration technique.

Therefore, in the present study, an attempt has been made to understand the distribution of macerals in Moonidih coal fines (BCCL) at different size and density fractions using image analysis technique. In addition to above, an attempt has also been made to understand the maceral enrichment by treating these coal fines in an enhanced gravity concentration unit.

EXPERIMENTAL

Sample

Coking coal fines were collected from Moonidh coal washery of Bharat Coking Coal Limited (BCCL) of Bihar state, India. The sample was sieved over 500 micron sieve and the oversize material was crushed to below 500 micron size and then sieved. The product so obtained was properly sampled using standard sampling procedures.

Size Analysis

Representative sample of coal fines was subjected to wet sieve analysis to understand the distribution of coal fines at various size fractions. The sample retained on each fraction was analyzed for ash content.

Sink-float Studies

Sink-float studies were carried out on feed coal sample using organic liquids such as Carbontetrachloride, Bromoform and Kerosene. The material floated on each density fraction was subjected to ash analysis to know the mineral matter distribution.

Block Preparation

The samples obtained at each size and density fraction were mounted in different blocks for petrographic analysis. The procedure adopted for the preparation of polished sections of coal samples is briefly explained below:

- Required quantity of sample was taken in to a grease-coated mounting thumb.
- About 1:2 ratio of hardener and epoxy resin of M/s Buehler make, USA, was poured into the thumb up to half of the volume.
- After thorough mixing the mixture of sample and resin-hardener, the remaining portion of the thumb was filled with diluted mixture of resin-hardener and allowed it for complete solidification.
- Specimen was removed from the thumb, labeled and then subjected for grinding and polishing as per the ICCP[17].

Image Analysis System

Image processing system used for the study essentially comprises a Leitz microscope, an image processing hardware system and a monitor. A 32 X/0.65 magnification oil immersion lens was used throughout the test programme. The image examined under the microscope was downloaded to image processor using a high-resolution video camera mounted on the top of the microscope. Each digitized sample image has an area of 0.2025m2 (450 X 450 pixels). This image is in the form of matrix of individual pixels and each pixel has a definite grey value based on brightness of the sample. The image analysis system software tools facilitates to analyze the downloaded image in a number of ways as per the requirement.

Procedure

The procedure followed for the examination of maceral groups is similar to the method adopted by Agus et al (1994). The methodology used in the present investigation is briefly described below :

The image examined under the microscope was downloaded to image processor. Macerals were identified on account of their micro-textural characteristics and reflectance. Image thresholding and segmentation was made based on the grey levels exhibited by the maceral groups. More attention was paid to minimize the curve-stripping of major macerals grey levels while doing image thresholding. The images analysed were stored in the memory and then integrated the grey levels. A typical grey level histogram obtained for a single image is shown in Fig. 1.

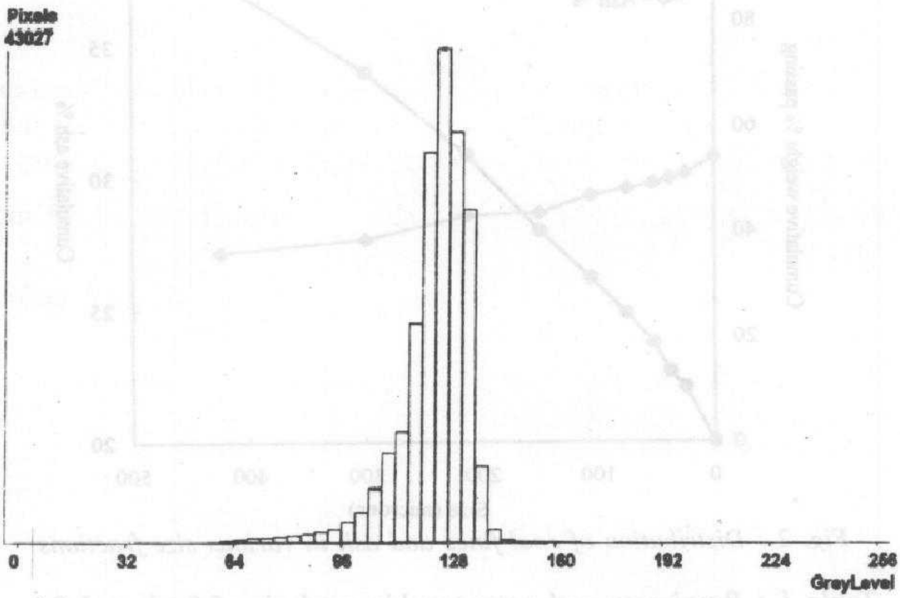

Fig. 1 : A typical grey level histogram obtained for completely liberated vitrinite group maceral

RESULTS AND DISCUSSION

Characterisation of Feed and Different Size Fractions

Sizewise distribution of coal fines and the corresponding ash content is shown in Fig. 2. It is clear from the figure that distribution of mineral matter is more or less same in all the size fractions.

Feed coal sample petrography shows that the presence of Vitrinite group maceral is abundant followed by Inertinite group maceral. Within the Vitrinite group the predominantly noticeable maceral is Telecollinite. A transitional maceral between Vitrinite and Semi-Fusinite termed as Semi-Vitrinite was also typically found in the sample. This finding reinforces the earlier observations[17]. The presence of Trimacerite (Vitrinite+Liptinite+Inertinite) particles were very common in medium size fractions. Major association of Vitrinite and Inertinite group maceral and mineral matter was noticed in the coarser size fractions. The mineral matter dissemination all through the macerals surface was identified in all size fractions, more particularly on Inertinite group macerals. Most of the macerals in coal sample were liberated at the size less than 25 micron. The proximate and petrographic analyses of feed sample are given in Table 1.

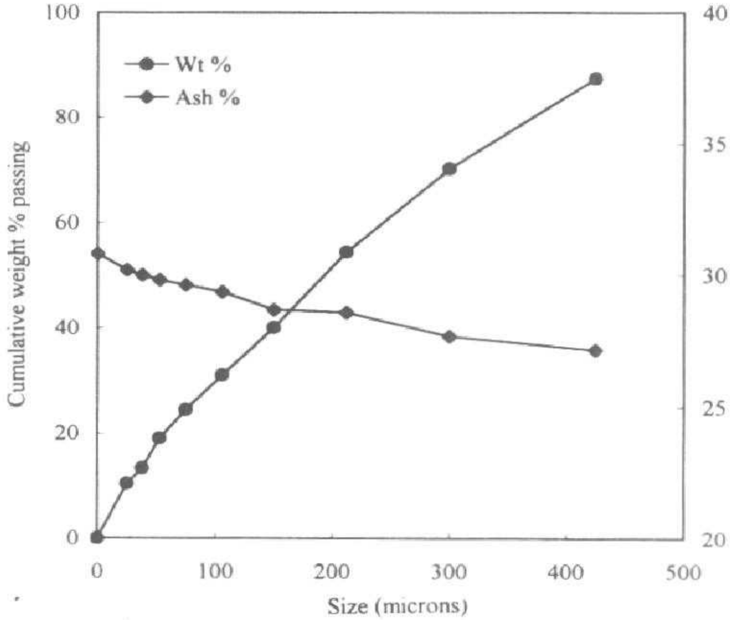

Fig. 2 : Distribution of coal fines and ash in various size fractions

Table 1 : Proximate and petrographic analysis of feed coal fines

Proximate Analysis	Weight %
Moisture	0.96
Volatile matter	13.74
Ash	30.78
Fixed Carbon	54.52
Petrographic Analysis	**Volume %(mmf)**
Vitrinite	51.86
Exinite (Liptinite)	4.24
Inertinite	28.00

mmf - visible mineral matter free basis

Characterisation of Macerals at Different Density Fractions

Macerals distribution at different density fractions was computed with image analyser and the same has been represented in terms of volume percentage in Fig.3. It can be observed from the figure that about 90% of Vitrinite group maceral floated at 1.3 density fraction. Vitrinite A (Telecollinite) is dominating maceral in Vitrinite group macarals. As proceeding to higher density fractions percentage of Vitrinite group maceral decreases while Inertinite group maceral increases. As expected, not many freely liberated Inertinite group macerals were floated at 1.4 density fraction because of association of mineral matter all over the surface. Image microphotographs observed at each density fraction are shown in Fig. 4. Completely liberated Inertinite group maceral i.e. Semi-Fusinite and Fusinite can be seen in Fig. 4(b). Exinite group maceral i.e Sporinite along with small or wide bands of Cutinites can be found in many of the Trimacerites floated at 1.5 to 1.8 density fractions. Bi-Macerite i.e. Vitrinite V proportion was more at 1.5 and 1.6 density fractions. Further, at 1.6 and 1.7 density fractions Inertinite group maceral was relatively abundant and majority of them was Semi-Fusinite and Inertodetrinite. Semi-Fusinite was dominant over Inertodetrinite by a ratio usually greater than 3:1. Mineral matter at 1.8 sink density fraction mainly consists of clay, quartz and few specks of pyrite.

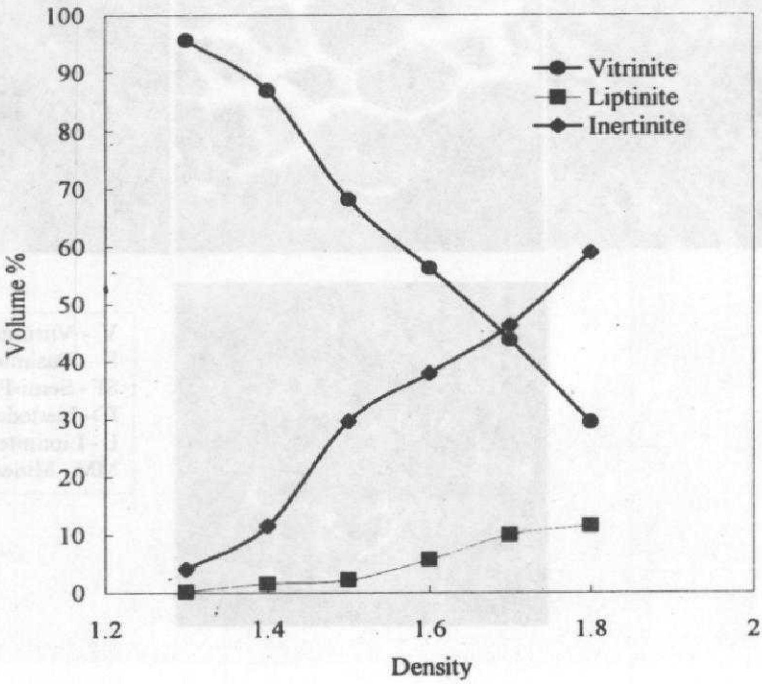

Fig. 3 : Distribution of macerals in various density fractions

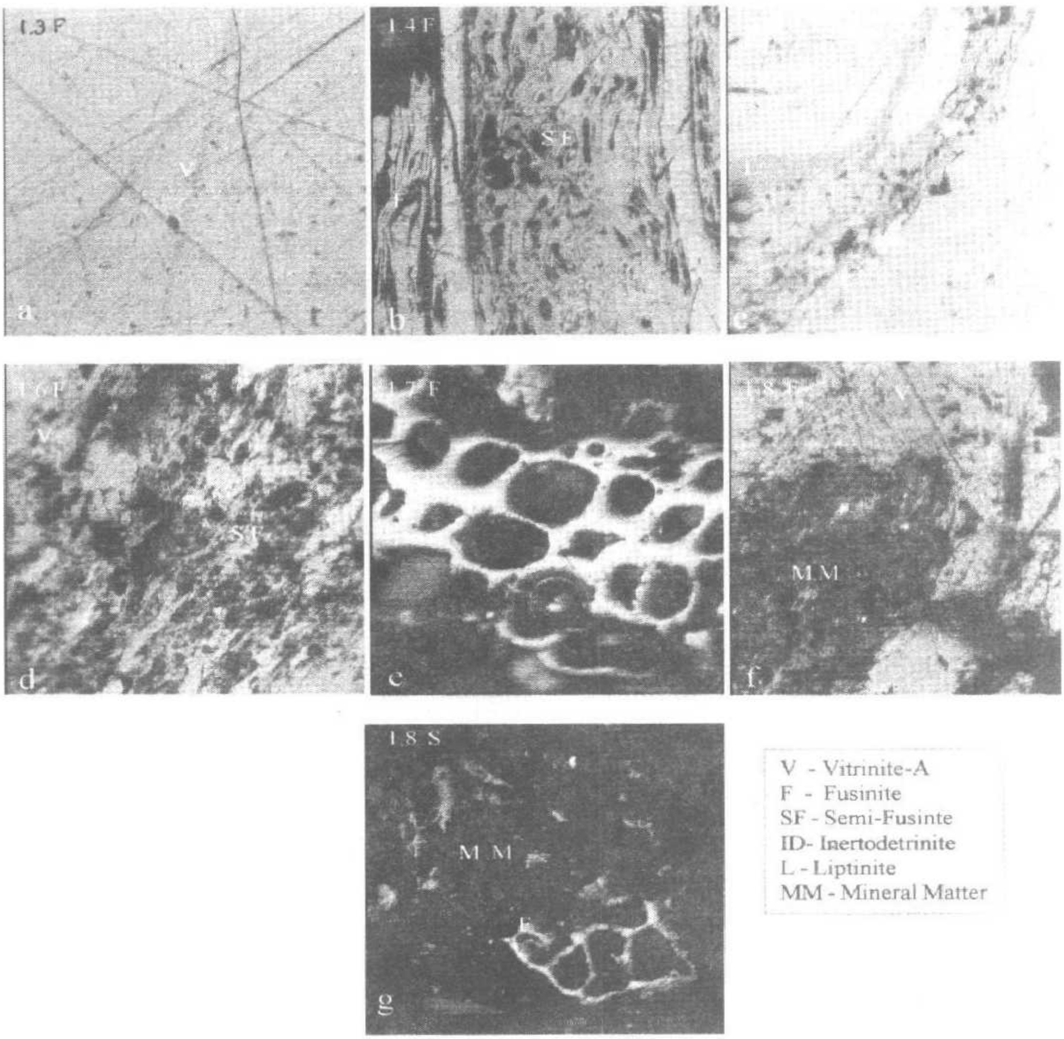

Fig. 4 : Image micrographs of macerals observed at various density fractions

Comparison of Conventional and Image Analysis Technique

Macerals distribution at different density fractions was computed with conventional point counter procedure also. Results obtained from image analysis technique were compared with conventional point counter method and the same is depicted in Fig. 5. It can be noticed from the figure that not much deviation exits between the results. The main drawback found in image analysis technique is that it is very difficult to differentiate between Liptinite and resin due to the similarity in their grey levels. Under these circumstances grain control and offset control adjustments were made to distinguish the same. However, it should be noted that the presence of Liptinite group maceral was very less in many of the Indian coals.

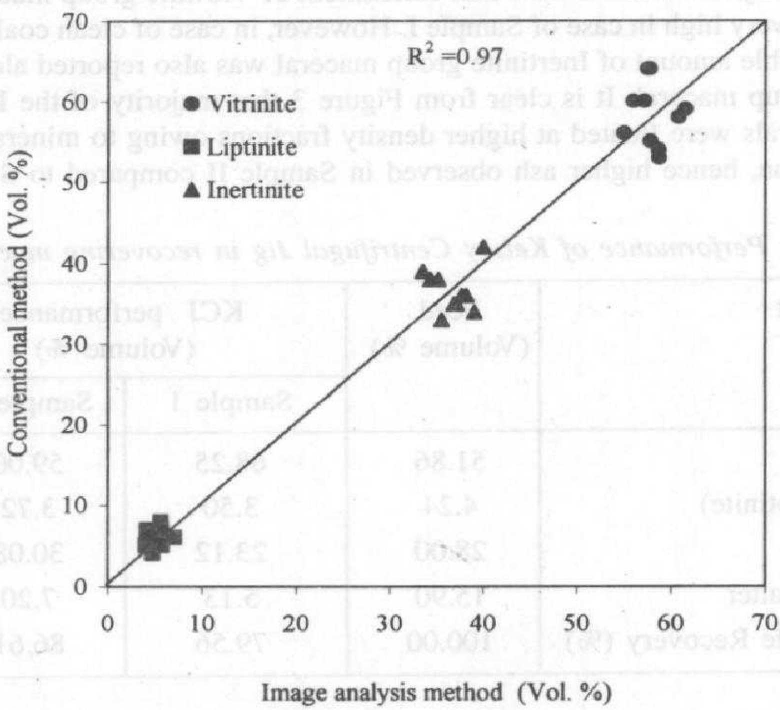

Fig. 5 : Comparison of conventional point count method and image analysis method

Enrichment of Macerals through Enhanced Gravity Technique

Macerals enrichment studies have been undertaken to asses the amenability of recently introduced enhanced gravity concentration unit i.e. Kelsey Centrifugal Jig (KCJ) in recovering the macerals based on the density differences between the macerals. A set of designed experiments was conducted on KCJ using the same feed material as used for petrographic analysis. Two clean coal products of KCJ were selected for maceral analysis and results observed are shown in Table 2. It can be seen from table that the presence of mineral matter (volume %) is only 5.13% and 7.20% for Sample I and Sample II respectively. However, the chemically determined ash is found to be 17.41% for Sample I and 21.65% for Sample II. Combustible recovery values were calculated using the following relation to assess the performance of KCJ in recovering coal particles and the same is given in Table 2.

$$\text{Combustible Recovery (\%)} = \text{\%Yield*} \times \frac{(100-\text{ Clean coal Ash \%})}{(100-\text{ Feed ash \%})}$$

*Yield % = Weight % of clean coal

Image analysis results reveals that enrichment of Vitrinite group maceral was found to be very high in case of Sample I. However, in case of clean coal Sample II, considerable amount of Inertinite group maceral was also reported along with Vitrinite group maceral. It is clear from Figure 3 that majority of the Inertinite group macerals were floated at higher density fractions owing to mineral matter contamination, hence higher ash observed in Sample II compared to Sample I.

Table 2 : Performance of Kelsey Centrifugal Jig in recovering macerals

Constituent	Feed (Volume %)	KCJ performance (Volume %)	
		Sample 1	Sample II
Vitrinite	51.86	68.25	59.00
Exinite(Liptinite)	4.24	3.50	3.72
Inertinite	28.00	23.12	30.08
Mineral Matter	15.90	5.13	7.20
Combustible Recovery (%)	100.00	79.56	86.61

CONCLUSION

The following conclusions can be drawn from the study:

- Petrographic analysis of coals using image analysis technique could be done at much faster rate with better accuracy as compared to conventional point counter method.
- Most of the macerals were liberated at the size less than 25 microns. The distribution of mineral matter observed to be common throughout the surface of the macerals in all size fractions.

- Inertinite rich Trimacerite observed to be abundant at higher density fraction whereas Vitrinite rich macerals proportion was found to be more at lower density fractions.
- It is possible to recover almost all the Vitrinite group macerals present in the feed sample employing enhanced gravity technique (KCJ).

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