The Influence the size and fusibility of inertinite components within coal grains has on coking properties

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17 April 2018
Introduction to Coal Grain Analysis (CGA)

- Semi automated image analysis method based on coal petrography methods
- Images are mosaicked together to provide detail on complete particles.

- Size and reflectance information provided for each particle
- Maceral and mineral components characterized in each particle.
- Reflectance values can be reported as “oil equivalent” values
Introduction to CGA

Processing example – Mosaic of images open in image processing software

• 14 bit colour images of a 10 x 10 image mosaic

• This image covers 4.2mm x 3.1mm

• Sample topsize of 1mm
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Processing example – Segmentation

- Image segmented
- Background resin removed
- Particles (grains) now processed individually
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Processing example – Characterisation

• Reflectance fingerprints obtained for each particle.

• Detailed information is determined for each individual particle, including:
  – composition (by maceral group),
  – reflectance
  – dimensions
  – Area
  – Internal component size
Introduction to CGA

Individual Grain Example

Segmented Grain

Characterized Grain

<table>
<thead>
<tr>
<th>Dark Mineral</th>
<th>Liptinite</th>
<th>Vitrinite</th>
<th>Inertinite</th>
<th>Bright Mineral</th>
</tr>
</thead>
</table>

6 | Introduction to CGA
Determining fusibility of Inertinite

Creation of matched surfaces
• 5 lumps for each coal
• Lumps cored then sectioned
• ½ of each lump coked

Schematic of matched surfaces made from a lump of coal
• joined together for comparison after one half has been coked (after Diessel, 1983)

Analysis of Matched Surfaces

Image of coal surface

Image of coke surface

Determining fusibility of Inertinite
Analysis of Matched Surfaces

Characterised coal image

Characterised coke image

Characterisation of coke performed by Pearson Coal Petrography
Determining the reflectance boundary

Coal

100 µm

Coke

Vitrinite
Fusible Inertinite
Infusible Inertinite
Liptinite
Dark Mineral
Bright Mineral

Unfused

Fused
Fusible inertinite range

Reflectance histogram (PDF)

Reflectance histogram (PDF)

Reflectance histogram (PDF)

Reflectance histogram (PDF)
Individual Grain Example - With the infusible inertinite identified
Size detail
Obtained for each structure in each particle of the coke oven feed sample

<table>
<thead>
<tr>
<th>Grain Statistics for Particle #21</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particle Image</strong></td>
</tr>
<tr>
<td>![Particle Image]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feret Min (µm)</th>
<th>1251.4</th>
<th>% Vitrinite (green)</th>
<th>58.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feret Max (µm)</td>
<td>2100.5</td>
<td>% Fus inerts (yellow)</td>
<td>15.6</td>
</tr>
<tr>
<td>Area (µm²)</td>
<td>1,581,717.9</td>
<td>% Infus inerts (pink)</td>
<td>14.4</td>
</tr>
<tr>
<td>Grain density</td>
<td>1.41</td>
<td>% Dark mins (red)</td>
<td>11.3</td>
</tr>
<tr>
<td>Grain ash</td>
<td>18.32</td>
<td>% Bright mins (aqua)</td>
<td>0</td>
</tr>
<tr>
<td>% of size fraction</td>
<td>0.93</td>
<td>% Liptinite (blue)</td>
<td>0</td>
</tr>
</tbody>
</table>

Grain Class: Vitrinite rich

<table>
<thead>
<tr>
<th>Excerpt of Internal Structure Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vitrinite</strong></td>
</tr>
<tr>
<td>Feret Min (µm)</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>1037.1</td>
</tr>
<tr>
<td>2.6</td>
</tr>
<tr>
<td>2.6</td>
</tr>
<tr>
<td>2.6</td>
</tr>
<tr>
<td>11.5</td>
</tr>
<tr>
<td>... 1292 structures in total</td>
</tr>
</tbody>
</table>

Subset of sizing data of individual structures within one particle of the -2+1mm sample for Coal A
Sample selection

A series of coke oven feed samples were prepared with
- The same overall composition
- The same overall grind
- Different mixes of coal grain types (very fine Inertinite rich fraction, to very coarse Inertinite rich fraction)

and then coke them all under the same conditions
- Bulk density: 825 kgm\(^{-3}\) (db)
- Charge moisture: 5%
- Heating conditions: wall temperature and coking time
Experimental Procedures

• 3 coals were coked five times in a 150kg pilot oven

<table>
<thead>
<tr>
<th>Coal Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACARP C16047</td>
<td>A High rank Moranbah / German Creek</td>
</tr>
<tr>
<td></td>
<td>B High rank Sydney Basin</td>
</tr>
<tr>
<td></td>
<td>C High rank Rangal</td>
</tr>
</tbody>
</table>

• All coals were specifically prepared to achieve the research purposes and do not represent commercial products
Combined CSR and Grind

- Coal A – very high CSR, little variation
- Coal B finer IRF grind → higher CSR
- The Rangal coal – the reverse
  - Although trends are weak in general
## Component size results

1 of the grind series - coarse inertinite

<table>
<thead>
<tr>
<th>REFLECTANCE ($R_{\text{me}}$)</th>
<th>COAL MEASURE</th>
<th>VOL % &gt;, &lt; 1.5MM</th>
<th>FUSIBLES</th>
<th>INFUSIBLES</th>
<th>TOTALS</th>
<th>COAL MEASURE</th>
<th>VOL % &gt;, &lt; 1.5MM</th>
<th>FUSIBLES</th>
<th>INFUSIBLES</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1-1.3</strong></td>
<td>Rangal</td>
<td>&lt;1.5mm</td>
<td>52.6</td>
<td>21.7</td>
<td>74.3</td>
<td>Illawarra</td>
<td>&lt;1.5mm</td>
<td>55.7</td>
<td>26.5</td>
<td>82.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;=1.5mm</td>
<td>17.8</td>
<td>8.0</td>
<td>25.7</td>
<td></td>
<td>&gt;=1.5mm</td>
<td>11.8</td>
<td>6.0</td>
<td>17.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>70.3</td>
<td>29.7</td>
<td>100.0</td>
<td></td>
<td>Total</td>
<td>67.4</td>
<td>32.6</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>1.3-1.5</strong></td>
<td>Rangal</td>
<td>&lt;1.5mm</td>
<td>54.3</td>
<td>21.7</td>
<td>76.0</td>
<td>Moranbah</td>
<td>&lt;1.5mm</td>
<td>57.2</td>
<td>17.4</td>
<td>74.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;=1.5mm</td>
<td>18.1</td>
<td>5.9</td>
<td>24.0</td>
<td></td>
<td>&gt;=1.5mm</td>
<td>23.5</td>
<td>1.9</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>72.4</td>
<td>27.6</td>
<td>100.0</td>
<td></td>
<td>Total</td>
<td>80.7</td>
<td>19.3</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Component size results

Infusibles

Lines darken with increasing coarseness of inertinite grind

Volume % Passing

Size (um)

Coal A
Coal B
Coal C
Component size results

- Variation in amount of infusible inertinite passing 1.5mm with inertinite rich fraction grind
  - Coal A and B – little variation seen
  - Coal C – less infusible inertinite material passing 1.5mm with increasing fineness of IRF grind, but dependent on 1 point
Summary

- Size detail can be obtained for the fusible and infusible structures present within individual particles.

- Subtle differences seen between 5 different grinds for each coal, however at this stage no systematic trends seen between the different grinds and coking properties.

- Large volumes of data generated by this study need to be interrogated further.
Other applications for CGA

Introduction
During the coking of coal of suitable rank, the organic material passes through a transformation wherein the vitrinite, fusinite, and some of the inertinite material are lost while the remaining inertinite material does not. During this process, some of the mineral grains in the parent coal may react and adversely affect the coke matrix surrounding it. To best quantify the effect of mineral grains on coke quality, it is necessary to consider the transformation, sort, and mineral grains during the coking process and their association with the organic material within the parent coal particle and in the resulting coke material.

Methodology

Sample Preparation

Cylinder, diameter tubes, were sampled from large, mineral-rich lumps of coal. The tubes were then cut along the axis of the cylinder and one of the half cylinders was selected (Warrer et al. 2016). The matching coal and coke halves were mounted in polymer resin and polished.

Optical Microscopy Analysis

- The coal half was analysed using CSIRO’s Coal Grain Analysis (CGA) optical reflected light microscopy imaging system to determine the relative distribution of the coal surface (Figure 1).
- The coke half was analysed by Pearson Coal Penetrometer (Pearson et al. 2012) to produce a map of the Coal and its reaction products in the surface of the coke lump (Figure 1, LM, & SEM).

The organic structures and the minerals in the coal halves were correlated with their corresponding coke-matrix structures and minerals in the coke halves (Figure 1).

Results

Figure 1 and 2 show the same individual grains analysed before and after the coking process with their respective species collected from SEM-Energy dispersive array (EDAX) spectra for each mineral component shown in Figure 2 and 8 shows their chemical compositions before and after the transformation process (Figure 2) showing Figure 2 shows the transformation of a silicate particle which was originally X-ray amorphous and had shock to approximately 0.5 kPa during the coking process, with slight differences in optical chemical composition. A similar result was observed for the transformation of the aluminosilicate (alumino-silicate) particles from coal (approximately yellow) and Coke (yellow) (Figure 2).

This result indicates that the coking and transformation of minerals in the coking process is very much based on chemical composition of the original minerals and their association with the organic material within the parent coal particles and in the resulting coke matrix.

Scanning Electron Microscopy Analysis

The coal and coke surfaces were further examined using a scanning electron microscope (SEM) to identify these coal and coke detail for the individual mineral grains in the matched coal and coke halves (Figures 2 and 3).

Analysis of matched coal and coke samples to determine mineral impacts on coke structures

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CSIRO PEARSON

Significant work has been conducted to develop a reference library of common dust particulates found in Australian environments. These reference particles are used to characterise coal dusts in dust samples using the CGA technique. An example of this is shown in Figure 1, where different dust particulates have been classified.

Applications of CGA

- Analysis of coal and coke dusts (catalysts) in emulsions in response to CGA
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Detecting and quantifying carbon resource dust particles using CGA

Michael Fazekas, Shalek Kato, and Shakes (2014) - CGA Energy
Thank you