Premium coal fuels with advanced coal beneficiation

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Introduction

• Greater resource recoveries are being sought by mine operators to maximize investment returns.
• Current industry trend - “by zero” recovery of fine coal to maximize resource yield and minimize environmental footprint.
• Fine coal size fraction faces the greatest barriers towards qualification as a product component.
• However, advances in liberation, flotation and dewatering create new opportunities for thermal coal operations. So .............

What are the historical barriers and how are they being overcome?

Why have advanced processing options now become viable?
Ultra-fine Coal Beneficiation

Two distinct approaches:

1. Chemical cleaning – coal structure is changed via chemical decomposition – potential is <0.2% ash residue.

2. Physical cleaning – coal structure not changed, but comminution may be applied for liberation – potential is <1% ash residue.

“Old school” thinking typically regards ash contents below 2-3%, as both technically and economically unviable because:

- “Inherent ash" of coal is usually regarded as the lowest achievable ash content
- Lower ash requires milling to finer particle size to increase liberation
- Flotation of ultra-fine coal can be problematic often requiring higher reagent dosages
- Fine coal concentrates are inevitably high in moisture (> 35%) which means costly dewatering and/or drying to produce saleable products.
Chemically Cleaned Coal

- Caustic leach process has been successfully demonstrated in Australia.
- Similar to the well-proven Bayer alumina process and also the AMAX 2-stage leach process developed with US-DOE funds in the mid-1980s.
- Ultra-low ash residue <0.2%
- Uses include slurry fuel or briquettes
- Costly option difficult to justify in current climate.
Liberation - Inherent ash constraint

CSIRO has developed an optical reflected light microscopy system for assessing coal petrography samples.

System collects and creates mosaic images so that quantitative information can be obtained on individual coal grains, i.e. **Coal Grain Analysis** (CGA).

CGA generally requires only small representative sub-samples of <1mm material.

Size and compositional information, i.e., **macerals** vitrinite, inertinite, liptinite and **minerals** can be determined for each particle.

Information can then also be used to estimate % mass, density & “ash” value of each particle.
Liberation – CGA Images Confirm Status

Characterised images for Raw Coal Tailings Feed compared with Final Concentrate. (Courtesy QCAT-CSIRO)
Flotation/Milling process approach

A 1tonne/h pilot-plant, owned and operated by Glencore Technology (formerly Xstrata) comprising

- two Jameson flotation cells,
- a small IsaMill, and a
- membrane filter press, etc.,
- Located at a large thermal coal operation in the Hunter Valley.

Currently testing freshly generated raw coal tailings to produce coal water slurry fuels
Milling and Sub-50µ Coal Flotation

NSW Coal Water Slurry Fuel (CWSF) Pilot Plant

- Successfully produces stable Coal Water Slurry Fuel (CWSF) from coal tailings
- CWSF can then be further refined to produce very low ash (<1% ash) Micronized Refined Coal (MRC)
- MRC produced from 2011 - 2015 for diesel engine tests
- Process information obtained also used for design of CWSF modules including a package plant and fuel handling rig.
Pilot Plant Fuel Production

Jameson cells
Flotation rig
Isa Mill
Fuel Preparation
Fuel Delivery
### Dewatering Technology

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Throughput (dry solids)</th>
<th>Product Moisture (% w/w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal belt filter</td>
<td>50-130 t/h</td>
<td>20-30</td>
</tr>
<tr>
<td>Screen bowl centrifuge</td>
<td>20-60 t/h</td>
<td>16-27</td>
</tr>
<tr>
<td>Centribaric centrifuge</td>
<td>15-20 t/h</td>
<td>15-20</td>
</tr>
<tr>
<td>Vacuum disc filter</td>
<td>50-150 t/h</td>
<td>20-32</td>
</tr>
<tr>
<td>Hyperbaric disc filter</td>
<td>30-150 t/h</td>
<td>17-25</td>
</tr>
<tr>
<td>Solid bowl centrifuge</td>
<td>10-18 t/h</td>
<td>18-25</td>
</tr>
<tr>
<td>Membrane Filter press</td>
<td>15-30 t/h</td>
<td>14-32</td>
</tr>
</tbody>
</table>

Key objective is to achieve a cake moisture of 20% or lower for ultrafines.
Emerging Coal Fines Treatment Circuit

2-Stage Flotation

High-rate thickener

Solid-bowl centrifuge
Ultra-fine coal
- 40 micron to <20% moisture

Screen-bowl centrifuge
+ 40 micron to 15-20% Moisture

Dewatering hydrocyclones

Solid-bowl centrifuge
Barren tailings
Solids disposal

High Pressure Briquetter

“New-age” product coal briquettes
- 15-20% Moisture
Wider Fines Treatment Options

- Micronised Refined Coal Production
- Coal Water Slurry Production
- Flotation Cell
- Best practice mechanical dewatering
- Agglomeration by briquetting
- Flotation Cell
- Fine Grinding
- Thermal Power Station Fuel
- Internal Combustion Engine Fuel
- New Tailings Disposal
- Product Stockpile

Plant Feed

Existing tailings dam

Flotation Circuit
Midsize Circuit
Coarse Circuit
Coal Supply Chain

• Current Coal Supply Chain (CSC) has been hampered by an inability to dewater and efficiently transport fine coal.
• Innovative approach - recover and use all the ultrafines via coal-water slurry thereby recovering potential “lost coal” creating higher yield and lower cost/tonne.
Innovative Coal Supply Chain

New Low-cost Fuel

- Coal-water slurry fuel (CWSF) at ~70% solids prepared from coarser (bi-modal) particle size distribution (p80 of 0.075 mm)
- Use for direct firing to boilers as a potential replacement for heavy fuel oil (HFO), or partial replacement for Pulverized Fuel (PF)
- Transport as slurry fuel - avoids sticky, wet or dusting coal problems
- Lower tailings disposal cost - paste-thickening, further dewatering for co-disposal with coarse plant discards and mining waste.

User Benefits

- No further grinding needed, significantly lowering cost
- Major O&M savings and lower ash disposal cost
- Reduced thermal efficiency offset by cost reductions from recovering lost coal from tailings.
- Potential to replace > 30% of the pulverised coal capacity.
- **Value Proposition:** a 1.0 to 1.5 c/kWh saving once the boiler has been converted for CWSF.
Micronized Coal Water Slurry

Optimization of the fuel cycle (DICE)

- Coal tailings sources
- Including tailings impoundments
- Increased grade recovery
- Recovery of ultra fines
- Minimal dewatering
- Road/rail/ship – cake or slurry
- Pipeline coal water fuels
- Higher solids paste for longer distance
- Mine-mouth or centralized
- Distributed generation
- Support of renewables

Ultra efficient diesel engine generation
Conclusions

• “Deep cleaning” via liberation and subsequent beneficiation has offered significant potential downstream improvements, i.e.,
  – maximised resource recovery,
  – minimised transport and handling costs,
  – numerous end-user process improvements,
  – reduced maintenance and wear,
  – lower environmental impacts and
  – other sustainable improvements.

• Ultrafine coal beneficiation has matured via progressive froth flotation improvements

• Dewatering the concentrate was a barrier, but emergence of membrane filter presses, hyperbaric disc filters or high-g decanter centrifuges now offers commercial solutions.

• Briquetting and agglomeration has progressed to machine capacities of up to ~40 ton/h for fine coal applications to improve product handling.

• Manufacture of stable coal-water slurries with > 65% solids and stable micronized slurries with > 60% solids have reached commercial adoption.

• **Scene is now set** for new generation clean coal technologies with minimal wasted energy, lowest ash disposal costs and reduced \( SO_x \), \( NO_x \) and \( CO_2 \) emission costs.
Acknowledgements

The authors acknowledge the contributions provided by

- Glencore Technology,
- Glencore Coal,
- Yancoal, and the
- CSIRO

towards the preparation of this paper and for permission to include figures and data from other recently published papers and articles on this subject.

Dave Osborne thanks Somerset Coal International for encouragement and support in attending and participating in the 2015 Clearwater Clean Coal conference.
Thank you for your time

Questions?
The Jameson Cell - Downcomer

Pressurized slurry enters downcomer through a nozzle at high velocity (typically 15-17 m/s). Typical feed pressure: 130-170 kPa (19-25 psi).

Jet plunges into slurry surface causing the entrained air to shear into fine bubbles. High intensity mixing leads to high probability of bubble-particle collision and contact.

Residence time in each downcomer is only several seconds. Slurry and the collected particles exit downcomer into tank where particle-laden bubbles are separated from the pulp.

Premium coal fuels with advanced coal beneficiation presentation
Product Coal Moisture Relationships

- Soil Water Characteristic Curve (SWCC), related to pore size distribution, in turn related to **Particle Size Distribution**\(^1\).
- Matric Suction is related to **Applied Pressure**

1 Source: Prof David Williams; Univ Queensland - *D.Williams@uq.edu.au*
## Coal Water Slurry Fuel

### Comparison of Coal Supply Chain Costs for Electricity Generation

<table>
<thead>
<tr>
<th></th>
<th>Mining</th>
<th>Preparation</th>
<th>Transport</th>
<th>Export Terminal</th>
<th>Sea Freight</th>
<th>Import Terminal</th>
<th>Transport</th>
<th>Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional Coal</strong></td>
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<tr>
<td>FOB 80 $/t</td>
<td>60 $/t</td>
<td>5 $/t</td>
<td>10 $/t</td>
<td>5 $/t</td>
<td>10 $/t</td>
<td>5 $/t</td>
<td>5 $/t</td>
<td>44 $/t</td>
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<tr>
<td>CIF 90 $/t</td>
<td>5 $/t</td>
<td>5 $/t</td>
<td>10 $/t</td>
<td>5 $/t</td>
<td>5 $/t</td>
<td>5 $/t</td>
<td>5 $/t</td>
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</tr>
<tr>
<td>Total Costs = 144 $/t</td>
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<tr>
<td></td>
<td>2.0 c/kWh</td>
<td>0.2 c/kWh</td>
<td>0.5 c/kWh</td>
<td>0.2 c/kWh</td>
<td>0.5 c/kWh</td>
<td>0.2 c/kWh</td>
<td>0.2 c/kWh</td>
<td>1.6 c/kWh</td>
</tr>
</tbody>
</table>

| **Coal Water Slurry** |         |             |           |                 |             |                 |           |             |
| FOB 36 $/t          | 20 $/t  | 11 $/t      | 5 $/t     | 11 $/t          | 5 $/t       | 6 $/t           |           | 47 $/t      |
| CIF 47 $/t          | 5 $/t   | 5 $/t       | 11 $/t    | 5 $/t           | 6 $/t       | 6 $/t           |           |             |
| Total Costs = 105 $/t |         |             |           |                 |             |                 |           |             |
|                      | 0.8 c/kWh | 0.5 c/kWh | 0.2 c/kWh | 0.5 c/kWh       | 0.2 c/kWh   | 0.2 c/kWh       | 0.2 c/kWh | 1.7 c/kWh   |