Development of Australian Brown Coal Reforming Technology for Power Generation

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Contents

§1. Background

§2. Overview of Brown coal reforming technology

§3. Reforming technology
   §3-1. Coal drying technology
   §3-2. Carbonization technology

§4. Conclusions
**Back ground**

**<Status of low rank coal usage>**
- Amount of low rank coal accounts for more than half of recoverable coal resources.

**<Disadvantages of Brown coal>**
- High moisture content
- Low calorific value
- Strong spontaneous heating

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![Diagram showing coal resources]

- **Brown coal (201 billion tons)**
- **Sub-bituminous coal (287 billion tons)**
- **Bituminous coal & anthracite (403 billion tons)**
- **Total: 892 billion tons**

Fig.1 Survey of coal resources
(ref.) WEC, 2013
Contents

§1. Background

§2. Overview of brown coal reforming technology

§3. Reforming technology
   §3-1. Coal drying technology
   §3-2. Carbonization technology

§4. Conclusions
Brown coal reforming technology

<Reforming process flow>

- **Drying**: To reduce moisture content.
- **Carbonization**: To increase calorific value.

Fig 2  Reforming process flow

<Key technologies of the reforming process>

- **Drying**: To reduce moisture content.
- **Carbonization**: To increase calorific value.
Change of calorific value

Aim of reforming

To convert Brown coal into an alternative power generation coal by increasing its calorific value.

Fig. 2 Reforming Process flow

Calorific target value is more than 27,000 kJ/kg!

Fig. 3 Change of Brown coal calorific value
Contents

§1. Background

§2. Overview of brown coal reforming technology

§3. Reforming technology
   §3-1. Coal drying technology
   §3-2. Carbonization technology

§4. Conclusions
Coal drying technology

<New development>

1. Improvement of total reforming energy efficiency.
   ⇒ Reusing waste steam from pyrolyzer.
   ⇒ Reusing waste steam from secondary drier by cascade use.

2. Safe temperature range for coal drying to prevent spontaneous heating.

3. The Primary Dryer with built-in indirect heating system to downsizing.

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Fig.4 Reforming process flow

- Primary dryer (Under development)
  - Air fluidized-bed
  - Moisture 60% → 30%

- Secondary drier (Conventional technology)
  - Steam moving-bed
  - Moisture 30% → 15%

- Pyrolyzer (Carbonization)
  - Waste steam
  - BFW

- Reformed coal

Moisture 100℃ → 30%
Laboratory equipment (6kg/batch scale)

<Experimental point>

- Condition of fluidization
- Drying characteristics:
  - Relationship between moisture content and coal temperature.

Fig.5  Laboratory equipment

Fig.6  Appearance

Air temperature : 80 ℃
Experiment

Coal sample: Loy Yang coal

Table.1 Proximate analysis

<table>
<thead>
<tr>
<th>TM(%)</th>
<th>VM (%)</th>
<th>FC (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.1</td>
<td>50.3</td>
<td>46.4</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Fig.7 Particle size distribution

Ave. $d_{50}$: 2.1 mm
(1). Condition of fluidization

<Experimental result>

- Hot air velocity ($U$: measured) > Fluidization velocity ($U_{mf}$: calculated) → Stable fluidization

![Section of fluidized-bed](image)

**Fig. 8** Section of fluidized-bed

**Fig. 9** Trend of $\Delta P$ in fluidized-bed

- Instability fluidization
- Stable fluidization

$D_p$: Particle size

$\rho_p$: Particle density [kg/m$^3$]

$\rho_g$: Air density [kg/m$^3$]

$\mu_g$: Air viscosity [kg/m.s]

$$
\frac{mg}{\rho g \rho_{mf}} g_D u^2 = 0.00075.
$$

$\Delta P$: Pressure drop

$\Delta P$ vs. Time [h:m]

$1$: 11:00, 11:30, 12:00, 12:30

$2$: 1:00, 11:30, 12:00, 12:30

$3$: 11:00, 11:30, 12:00, 12:30

$4$: 11:00, 11:30, 12:00, 12:30

$\Delta P$ [KPa]

Time [h:m]
(2). Relationship between moisture content and temperature

<Result>

- When coal temperature is constant. ⇒ Moisture content range: 60%~25%
- When coal temperature increase. ⇒ Moisture content: under 25%
Feature of Primary Dryer (700kg/h)

- Improvement of total drying energy efficiency by **using waste steam** from the Secondary Dryer.
- **Drying temperature < 60°C** to avoid spontaneous heating.
- Primary Dryer has **two heat sources**:
  1) **Direct heating system** with hot air.
  2) **Indirect heating system** with steam tubes (built-in).

⇒ Target capacity has been achieved by the pilot test. (700kg/h)
(3). Drying capacity and safety

<Experimental result>

- Coal temperature < 60°C during constant-rate drying was achieved. ⇒ Safety coal temperature range(<60°C) with air drying was confirmed feasible.

![Diagram showing trend of coal temperature](image)

Fig.12 Trend of coal temperature
(4). Drying effect by built-in indirect heating tubes

<Experimental result>

1) Heat exchange capacity of drying floor area was doubled by indirect heating steam tubes.
2) Evaporative water of drying floor area was doubled.
   ⇒ drying capacity increased at same hot air  ⇒ **Reduction of hot air**
§3-1. Summary

<Coal drying technology>

1) Reforming energy efficiency increased by utilization of waste steam.

2) Safe coal temperature drying was achieved with air fluidized-bed.

3) Downsizing of equipment was achieved by built-in indirect heating steam tubes.
Contents

§1. Background

§2. Overview of brown coal reforming technology

§3. Reforming technology
   §3-1. Coal drying technology
   §3-2. Carbonization technology

§4. Conclusions
Using volatile matter (VM) gas as fuel from Pyrolyzer.
⇒ Without fuel of outside to improve reforming energy efficiency.
Carbonization technology

<Concept (2)>

Increasing of calorific value of raw coal is equivalent to steam coal (more than 27,000 kJ/kg) by carbonization.

Target value is more than 27,000 kJ/kg! ÷ Steam coal

Table 2 Analysis data

<table>
<thead>
<tr>
<th></th>
<th>Ultimate analysis [mass%, d.a.f.]</th>
<th>Proximate analysis [mass%-dry]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>H</td>
</tr>
<tr>
<td>Raw Coal</td>
<td>67.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Reformed Coal</td>
<td>79.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

C: Increase  O: Decrease

Fig.17 Calorific value of Brown Coal
Relationship between temperature and VM

<Result>

VM gas fired as fuel

⇒ Heat requirement of Dryer and Carbonization.

⇒ VM25% is the most suitable for reformed coal of our project.

Fig.18 Heat requirement of drying and carbonization
### Relationship between VM and Calorific value

**<Result>**

1) Strong correlation between carbonization temperature, VM and calorific value.
2) Calorific value of reformed coal (VM 25%) is equivalent to steam coal.

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<tr>
<td>Coal A</td>
<td>71.6</td>
<td>5.1</td>
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<tr>
<td>Coal B</td>
<td>78.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Coal C</td>
<td>81.3</td>
<td>5.0</td>
</tr>
</tbody>
</table>

![Fig.19 Relationship between VM and calorific value](image)

- Raw coal
- Reformed coal
- Coal A
- Coal B
- Coal C

Steam coal

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§3-2. Summary

<Carbonization technology>

1) Correlation between carbonization temperature, VM and calorific value has strong.

2) Calorific value of reformed coal is equivalent to steam coal calorific value. (more than 27,000 kJ/kg)
Contents

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§2. Overview of brown coal reforming technology

§3. Reforming technology
   §3-1. Coal drying technology
   §3-2. Carbonization technology

§4. Conclusions
Conclusions

<Coal drying technology>

1) Reforming energy efficiency was increased by utilization of waste steam.

2) Safety coal temperature drying was achieved with air fluidized-bed.

3) Downsizing was achieved by indirect heating steam tubes.

<Carbonization technology>

1) Calorific value of reformed coal was increased by carbonization technology. (more than 27,000 kJ/kg)

⇒ Suitable for power generation.
Future tasks

1) Preparation of demonstration project in Australia.
   - Validity in scale-up procedure
   - Effects of long term operation

2) Study on application of other raw coals.
Acknowledgment

This presentation is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).
We sincerely expect the Success of this Project by cooperation with both countries!

Thank you for your kind attention!