Introduction of TIGAR® and research activities related to Polish coals

*TIGAR® (Twin Ihi GAsifieR) is under development.*

IHI Corporation
1. Introduction of IHI

2. Introduction of TIGAR®

3. Collaboration between Poland and IHI
   • Background
   • Gasification test results of Polish coals
   • Plan of collaboration project

4. Summary
IHI Corporation Profile

- Founded: 1853
- Net Sales: JPY 1,304,000 mil (USD 13,165 mil)
- Works: 10
- Branch Offices: 18 (Japan), 14 (Overseas)
- Subsidiaries: 251

Total Sales Volume / as of March 31, 2014

- Social Infrastructure and Offshore Facilities: 30%
- Aero Engines and Space: 30%
- Resources, Energy and Environment: 26%
- Industrial Systems and General-Purpose Machinery: 29%
- Others: 4%

The First Steamship Built by Japanese Private Company – “Tsu-un maru”.

Global Network

Overseas Office
- Global Subsidiary Company

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Several types of boilers for the best Usage of fuel
- Increasing plant efficiency by the improvement of steam condition
- CO₂ capture and storage by Oxy-fuel combustion in Callide, Australia
- Flexible & lower-cost gasifier for effective utilization of low rank coal
Characteristics of TIGAR®

- The low grace energy (lignite, biomass) which was difficult technically/economically for use can be gasified, and it uses effectively for a chemical raw material or fuel.

**Applicable materials**

“Fuel diversification”
- Coal (low rank coal)
- Wood
- Palm Waste

**Multi product application**
- NH3 product
- Fuel cell
- SNG
- CTL
- Chemical feedstock
- DME
- Auto fuel

**Syngas**
- Shift
- Reforming
- Synthesis

**Syngas component** at gasifier outlet
- H2: 51%
- CH4: 19%
- CO: 18%
- CO2: 9%
- Other HC: 3%

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Components of TIGAR® are based on mature CFB and BFB technology.

**Operation condition**
- Atmospheric pressure
- Low temperature

**Compressors**
- (heat emission)

**Gasifier**
- (heat absorption)

**Fuel/materials**

Air

Steam
**Characteristics of TIGAR®**

1. **Lower CAPEX and simple Operation & Maintenance**
   - Lower pressure and lower temperature in operating condition
2. **Simple Fuel preparation**
   - Coarse size and higher moisture are acceptable
3. **No N₂ contamination in Syn-gas, because of Steam gasification**

<table>
<thead>
<tr>
<th>IHI -TIGAR-</th>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gasifier type</strong></td>
<td>Fluidized bed</td>
<td>Entrained bed</td>
<td>Moving bed</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>Atmospheric</td>
<td>&gt;3MPa</td>
<td>&gt;3MPa</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>800-1,000°C</td>
<td>&gt;1,400°C</td>
<td>&gt;1,400°C</td>
</tr>
<tr>
<td><strong>Gasification agent</strong></td>
<td>Steam</td>
<td>Oxygen</td>
<td>Oxygen</td>
</tr>
<tr>
<td><strong>Fuel particle size</strong></td>
<td>&lt;10mm</td>
<td>&lt;0.1mm</td>
<td>&lt;0.1mm</td>
</tr>
<tr>
<td><strong>Fuel configuration</strong></td>
<td>Bulk, powder</td>
<td>Powder</td>
<td>Slurry</td>
</tr>
<tr>
<td><strong>Applicability for lignite coal</strong></td>
<td>◎</td>
<td>○</td>
<td>△</td>
</tr>
<tr>
<td><strong>Residue</strong></td>
<td>Dry Ash</td>
<td>Slag</td>
<td>Slag</td>
</tr>
</tbody>
</table>
Target of TIGAR®

Applied class of capacity and feedstock

- Low Volatile
  - Anthracite
  - Bituminous
  - Sub-bituminous
  - Lignite
  - Biomass

- High Volatile

Capacity / 1 unit

- 300t/d
- 1000t/d
- 2000t/d

- Entrained bed type gasifier
- Dry Feed Entrained bed type gasifier

Low Rank Coal and Biomass

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TIGAR® Development schedule

Japanese Government (METI*) Support


Basic Test 6TPD Pilot Plant

50TPD Prototype Plant EPC Demonstration Test Commercial Plant

6TPD@Yokohama, JAPAN 50TPD@Kujang, INDONESIA

Commercial plant image

Coal feed : 3000 TPD (Substantially NH₃ : 1000 TPD)

TIGAR × 4units (1 site)

*Ministry of Economy, Trade and Industry

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【Purpose】

Check the maintenance durability in long operation (Total 4,000 hr operation) using Indonesia lignite.

<50t/d plant spec>

<table>
<thead>
<tr>
<th>Coal feed rate</th>
<th>50ton/day (as received, 43% moisture)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syngas output</td>
<td>1,800m³N/h-dry</td>
</tr>
<tr>
<td>Steam generation</td>
<td>4.5t/h (2.0MPaG, 513deg.C)</td>
</tr>
<tr>
<td>Site area</td>
<td>100m × 80m</td>
</tr>
</tbody>
</table>
Collaboration between Poland and IHI

2012
- IHI gave a presentation about TIGAR® for Polish government and AGH at AGH Univ. and Yokohama

2013
- IHI discussed with AGH, GIG and IChPW about the collaboration project
- PGE and GIG provided coal samples to IHI
- Gasification tests had been conducted by IHI
  - Properties Analysis of Polish coals
  - Gasification experiments
  - Prediction of gasification performance

2014
- IHI will start the collaboration project with Polish partner about Pre-FS of TIGAR® applications

All events and research were supported by JCOAL.
Energy balance of Poland

- Coal: 86%
- Oil: 2%
- Natural gas: 4%
- Hydro: 1%
- Others: 7%

163 TWh

From IEA 2012

Natural gas in Poland

- Import: 75%
- Domestic: 25%

14 Billion m³

From report of Europe Business services

- 25% of coal reserve is lignite.
- 90% of import natural gas depends on Russia. The price of natural gas is higher than that of USA.

- If gaseous fuel can be obtained from plentiful Polish lignite, that will be greatly beneficial for Poland.
### Properties Analysis of Polish coals

**Proximate, Ultimate Analysis etc.**

Investigate the properties of coal that effect the activity of gasification reaction

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BELCHATOW</th>
<th>TUROW</th>
<th>BOGDANKA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate analysis (wt% air dried basis or specify)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture (as received)</td>
<td>51.7</td>
<td>45.0</td>
<td>8.47</td>
</tr>
<tr>
<td>Moisture</td>
<td>17.6</td>
<td>18.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Ash</td>
<td>14.9</td>
<td>4.2</td>
<td>24.7</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>38.8</td>
<td>45.6</td>
<td>31.1</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>28.7</td>
<td>32.0</td>
<td>42.8</td>
</tr>
<tr>
<td><strong>Ultimate analysis (wt% dry basis)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>54.28</td>
<td>68.26</td>
<td>59.92</td>
</tr>
<tr>
<td>H</td>
<td>4.19</td>
<td>5.68</td>
<td>4.08</td>
</tr>
<tr>
<td>S (total)</td>
<td>1.21</td>
<td>0.32</td>
<td>0.96</td>
</tr>
<tr>
<td>S (combustible)</td>
<td>0.28</td>
<td>0.06</td>
<td>0.91</td>
</tr>
<tr>
<td>S (uncombustible)</td>
<td>0.93</td>
<td>0.26</td>
<td>0.05</td>
</tr>
<tr>
<td>N</td>
<td>0.42</td>
<td>0.45</td>
<td>1.29</td>
</tr>
<tr>
<td>Ash</td>
<td>18.10</td>
<td>5.10</td>
<td>25.10</td>
</tr>
<tr>
<td>O (different)</td>
<td>22.73</td>
<td>20.45</td>
<td>8.70</td>
</tr>
<tr>
<td>Calorific value (J/g)</td>
<td>17570</td>
<td>22980</td>
<td>24150</td>
</tr>
<tr>
<td>Calorific value (J/g) a.r.</td>
<td>10300</td>
<td>15450</td>
<td>22420</td>
</tr>
</tbody>
</table>

- **Lignite**
- **Lignite**
- **Bituminous**

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=Hard coal
TUROW has the same reactivity for gasification with Indonesian coal, while BELCHATOW has 30% higher.

Polish lignite is applicable to TIGAR® process.
Which applications of TIGAR® will be suitable in Poland?
Collaboration project with Polish partner

◆ Title
Marketing research of TIGAR® in Poland (supported by JCOAL)

◆ Purpose
To investigate an appropriate utilization of syngas from TIGAR® in Poland

◆ Research contents

<table>
<thead>
<tr>
<th>Research items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation of Polish energy situation</td>
</tr>
<tr>
<td>Investigation of market for syngas from TIGAR®</td>
</tr>
<tr>
<td>Estimation of feasible CAPEX and OPEX</td>
</tr>
<tr>
<td>Discussion with potential customers</td>
</tr>
<tr>
<td>Summary</td>
</tr>
</tbody>
</table>

◆ Schedule

- Gasification test 2013
- Pre-FS 2014
- FS 2015
TIGAR® is expected to become widely used because of lower CAPEX and simple operation, maintenance and fuel preparation.

This year, we will start the demonstration operation with 50TPD in Indonesia.

Polish lignite is applicable to TIGAR® process.

Future plan

IHI will continue to conduct a feasibility study of TIGAR® by using Polish coal and keep in touch with Polish partner.
Acknowledgment

Investigation of gasification performance with Polish coal is supported by Japan Coal Energy Center. (JCOAL)

TIGAR® Proto-type plant project is supported in part by the Ministry of Economy Trade and Industry of Japan. (METI)
IHI
Realize your dreams