Advances in Coal Gasification Technology and Gaseous Hydrocarbon Conversion Technology of ECUST

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East China University of Science and Technology
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1. Introduction of ICCT

- Institute of Clean Coal Technology (ICCT) since 1995
- ~100 people (19 faculties including 7 Prof., 9 Associate Prof., and about 100 graduate students)
- Coal Gasification Technology Research Center of National Energy Administration
- Co-R&D center of ECUST and SINOPEC
- Gasification Engineering Center of Shanghai
1. Introduction of ICCT

ICCT focus on the entrain flow coal gasification: fundamental research, technological development, industrial application.

Raw material:
Coal/petroleum coke/nature gas

Product/Scale

Technology
Feedstock:
Slurry/Particle/Gas

Gasifier:
Muti/Solo-Burner

Lining:
Brick/Membrane

Heat recovery:
Quench/Radiation

Gasification Technology

OMB CWS gasification technology

OMB dry feed gasification technology

Non-Catalyst POX technology Radiant syngas cooler gasification technology SE dry feed gasification technology
2. CWS Gasification Technology

ECUST Coal Gasification Technologies

Opposed Multi-Burner (OMB) Coal-Water Slurry (CWS) Gasification Process

SE Dry-feed Coal Gasification Process
2. OMB CWS Gasification Technology

OMB R&D History

- **Innovation & Pilot Plant** 22TPD
  - 1996~2000
- **Industrial Demo.** 1150TPD 750TPD
  - 2001~2005
- **Scale up** 2000TPD
  - 2006~2010
- **Scale up** 3000TPD
  - 2011~2015
- **Scale up** 4000TPD
  - 2016~2020

Hi-tech Research and Development Program (863 Program)

“Ultra-large scale CWS gasification key technology research and waste water reduction” (2017-2021)
2. OMB CWS Gasification Technology

OMB CWS gasification technology process diagram
Technology Features

- High carbon conversion and low oxygen/coal consumptions: opposed burner and better mixing process
- Easy to scale up (2000-4000 TPD): multi-burner
- High efficiency of syngas primary purification section: low process pressure drop and low fly-ash content in syngas (<1 mg/Nm$^3$ syngas) using “multi-stages” method
- High heat recovery efficiency and stability in slag water treatment section: direct heat exchange between grey water and vapor from flash of slag water
2. OMB CWS Gasification Technology

Industrial Applications

<table>
<thead>
<tr>
<th>Des. Cap. Per Gasifier</th>
<th>Num. of Projects</th>
<th>Num. of Gasifiers</th>
<th>Num. of Projects in Operation</th>
<th>Num. of Gasifiers in Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000 TPD</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>~1000 TPD</td>
<td>10</td>
<td>23</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>~1500 TPD</td>
<td>11</td>
<td>28</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>~2000 TPD</td>
<td>16</td>
<td>46</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>&gt;2500 TPD</td>
<td>15</td>
<td>54</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td><strong>Sums</strong></td>
<td><strong>56</strong></td>
<td><strong>158</strong></td>
<td><strong>29</strong></td>
<td><strong>77</strong></td>
</tr>
</tbody>
</table>

Gasifier capacity ~2000 t/d and above > 60%

- 56 projects (158 gasifiers)
- The total capacity of coal for all projects is >200,000 TPD
- The capacity of single gasifier ranges from 650 to 4000 TPD
2. OMB CWS Gasification Technology

Operation projects started up this year

Hengli Petrochemical
(Dalian) Refinery Co., Ltd.

- Gasifiers: 5+1 (3000 TPD)
- Pressure: 6.5MPa(G)
- Products: Hydrogen & gas
- Syngas (CO+H₂) flowrate: 1,000,000Nm³/h
- Start up: Feb. 15, 2019
2. OMB CWS Gasification Technology

Latest operation projects

Inner Mongolia Rongxin (phase II) Coal Chemical Co., Ltd.
Gasifiers: 2+1 (4000 TPD)  Pressure: 6.5MPa(G)
Start up: 15:46 on Oct. 29, 2019 (local time)
2. OMB CWS Gasification Technology

Latest progress of “big project”

Zhejiang Petrochemical Refinery Co., Ltd.
Phase I and II

- Gasifiers: 8+4 (3000 TPD)
- Pressure: 6.5MPa(G)
- Products: Hydrogen & gas
- Syngas (CO+H2) flowrate: 1.4 million Nm3/h
- Start construction: Jun. 9, 2017
- Scheduled commissioning time: Nov, 2019
2. OMB CWS Gasification Technology

Yankuang Yulin Energy Chemical Co. Ltd.

- Gasifiers: 2+1 (2000 TPD), 2 quenching / 1 RSC
- Pressure: 6.5MPa(G)
- Products: DMMn
- Scheduled commissioning time: Nov, 2019
2. OMB CWS Gasification Technology

Radiant Syngas Cooler (RSC) – Quenching Combination Gasification Technology
Radiant syngas cooler (RSC)

--- OMB CWS gasification tech.

- Higher gasification efficiency than quenching process.
- By optimizing the combination of RSC and Quench chamber to adjust the syngas temperature and the steam/syngas ratio.
- Producing high pressure steam can meet the requirement of downstream, lower the coal consumption and pollutant emission.
2. OMB CWS Gasification Technology

Latest progress of RSC gasifier

The radiant syngas cooler

The gasifier shell
2. OMB CWS Gasification Technology

<table>
<thead>
<tr>
<th>Feeding Stocks</th>
<th>Gasification Pressure</th>
<th>Gasifier Diameter</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>1.5 MPa(G)</td>
<td>2800 mm</td>
<td>750 TPD</td>
</tr>
<tr>
<td>Petcoke</td>
<td>4.0 MPa(G)</td>
<td>3200 mm</td>
<td>850 TPD</td>
</tr>
<tr>
<td>Sludge</td>
<td>4.1 MPa(G)</td>
<td>3400 mm</td>
<td>1150 TPD</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>4.2 MPa(G)</td>
<td>3600 mm</td>
<td>1200 TPD</td>
</tr>
<tr>
<td></td>
<td>6.2 MPa(G)</td>
<td>3880 mm</td>
<td>1500 TPD</td>
</tr>
<tr>
<td></td>
<td>6.5 MPa(G)</td>
<td>4000 mm</td>
<td>1800 TPD</td>
</tr>
<tr>
<td></td>
<td>8.7 MPa(G)</td>
<td>4200 mm</td>
<td>2000 TPD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heat Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quenching Process</td>
</tr>
</tbody>
</table>
3. SE Dry-feed Gasification Technology

SINOPEC-ECUST
3. SE Dry-feed Gasification Technology

**Pulverized Coal Preparation**

- Raw Coal
- Hot N₂
- N₂ or CO₂
- Coal mill
- Feed Hopper
- Atmosphere Hopper
- Lock Hopper

**Gasifier**

- Pulverized Coal
- Oxygen Steam
- Water Wall Gasifier
- Cyclone
- Mixer
- Slag Lock Hooper
- Slag

**Primary Purification**

- Water scrubber
- Synthetic gas
- Condensate
- Sour gas
- Evaporative hot-water tower

**Solid Water Treatment**

- Gray water

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Single burner jet gasifier with membrane-wall liner
3.1 Industrial applications

- Sinopec Yangzi PetroChemical Co., Ltd Phase I (1 × 1000 TPD) Jan. 2014
- ZhongAn Joint Coal Chemicals Co., Ltd (7 × 1500 TPD) Jun. 2019
- Sinopec Yangzi PetroChemical Co., Ltd Phase II (1 × 1000 TPD) Nov. 2019
- Changcheng Energy Chemical (Guizhou) Co., Ltd (5 × 1500 TPD) Mar. 2023

SE Gasifier

ZhongAn gasification Plant
3.2 Progress of ZhongAn Coal-Chemicals Project

ZhongAn Joint Coal Chemicals Co.,
Gasifiers: 5+2 (1500 TPD)
- Pressure: 4.0 MPa(G)
- Products: Ethylene Glycol
- Syngas (CO+H₂) flowrate: 500,000Nm³/h
- Start Up: Jun. 15, 2019
### 3.2 Progress of ZhongAn Coal-Chemicals Project

#### Gasification performance (Ash~18%, FT~1300℃)

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>5#</th>
<th>6#</th>
<th>7#</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulverized coal</strong></td>
<td>t/h</td>
<td>52.0</td>
<td>48.5</td>
<td>46.0</td>
</tr>
<tr>
<td><strong>Oxygen</strong></td>
<td>t/h</td>
<td>39.4</td>
<td>39.9</td>
<td>39.3</td>
</tr>
<tr>
<td><strong>Steam</strong></td>
<td>kg/h</td>
<td>2447</td>
<td>3081</td>
<td>4136</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>MPa</td>
<td>3.77</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td><strong>Raw syngas</strong></td>
<td>kg/h</td>
<td>130189</td>
<td>124470</td>
<td>136877</td>
</tr>
<tr>
<td><strong>Steam product</strong></td>
<td>t/h</td>
<td>10.5</td>
<td>8.2</td>
<td>11.1</td>
</tr>
<tr>
<td><strong>Syngas composition</strong></td>
<td>CH4 ppm</td>
<td>80</td>
<td>75</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>H2%</td>
<td>25.3</td>
<td>26.1</td>
<td>27.1</td>
</tr>
<tr>
<td></td>
<td>CO%</td>
<td>63.6</td>
<td>64.1</td>
<td>61.6</td>
</tr>
<tr>
<td></td>
<td>CO2%</td>
<td>9.4</td>
<td>8.6</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>N2%</td>
<td>1.4</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>
3.2 Progress of ZhongAn Coal-Chemicals Project

Gasification performance

<table>
<thead>
<tr>
<th>采样日期</th>
<th>装置名称</th>
<th>采样点</th>
<th>样品名称</th>
<th>干基残碳含量 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019-07-28 20:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.28</td>
</tr>
<tr>
<td>2019-07-29 08:00:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.51</td>
</tr>
<tr>
<td>2019-07-29 08:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.99</td>
</tr>
<tr>
<td>2019-07-29 20:00:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.33</td>
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<tr>
<td>2019-07-30 08:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.21</td>
</tr>
<tr>
<td>2019-07-30 08:00:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.95</td>
</tr>
<tr>
<td>2019-07-30 08:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.02</td>
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<tr>
<td>2019-07-30 20:00:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.36</td>
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<tr>
<td>2019-07-31 08:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>1.31</td>
</tr>
<tr>
<td>2019-07-31 08:00:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.33</td>
</tr>
<tr>
<td>2019-07-31 20:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.36</td>
</tr>
<tr>
<td>2019-08-01 08:00:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.33</td>
</tr>
<tr>
<td>2019-08-01 08:00:00</td>
<td>煤气化装置</td>
<td>7#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.33</td>
</tr>
<tr>
<td>2019-08-01 14:30:00</td>
<td>煤气化装置</td>
<td>6#X-1401出口稀</td>
<td>气化炉渣</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Combustible content in coarse slag <1%
3.2 Progress of ZhongAn Coal-Chemicals Project

Gasification performance

Combustible content in fine slag ~15% on average

<table>
<thead>
<tr>
<th>品名名称</th>
<th>干基残炭含量 (%)</th>
<th>水含量 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.59</td>
<td>47.6</td>
</tr>
<tr>
<td></td>
<td>19.33</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td>15.38</td>
<td>50.7</td>
</tr>
<tr>
<td></td>
<td>19.39</td>
<td>51.7</td>
</tr>
<tr>
<td></td>
<td>19.54</td>
<td>51.8</td>
</tr>
<tr>
<td></td>
<td>14.04</td>
<td>48.80</td>
</tr>
<tr>
<td></td>
<td>12.00</td>
<td>44.10</td>
</tr>
<tr>
<td></td>
<td>17.44</td>
<td>48.6</td>
</tr>
<tr>
<td></td>
<td>17.66</td>
<td>50.1</td>
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<td></td>
<td>15.00</td>
<td>47.7</td>
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<td></td>
<td>14.77</td>
<td>48.0</td>
</tr>
<tr>
<td></td>
<td>11.21</td>
<td>41.1</td>
</tr>
<tr>
<td></td>
<td>10.69</td>
<td>40.9</td>
</tr>
</tbody>
</table>

Carbon conv. ~99%, Ratio of fine/coarse slag: ~3/7
3.3 Progress of ZhongKe PetroChemical Project

Guangdong Zhongke PetroChemical Co., Ltd

- Gasifiers: 1+1 (2000 TPD)
- Pressure: 4.0 MPa(G)
- Products: H2
- Syngas (CO+H₂) flowrate: 130,000Nm³/h
- Mechanical completion: ~ Jan. 2020
- Coal: Australia bituminite with high FT
Changcheng Energy Chemical (Guizhou) Co., Ltd

- (5×1500 TPD)
- Gasifiers: 5+1 (1500 TPD)
- Pressure: 4.0 MPa(G)
- Products: Polyolefin
- Syngas (CO+H2) flowrate: 500,000Nm3/h
- Mechanical completion: ~ Jan. 2023
- Coal: Guizhou anthracite with high FT and ash content
4. ECUST’s NC POX technology

- Since 1980s, ICCT-ECUST began to research the hydrocarbon steam reforming and NC POX technologies.
### 4.1 Industrial Applications

<table>
<thead>
<tr>
<th></th>
<th>Company name</th>
<th>Pressure (MPa)</th>
<th>Reformer/Process</th>
<th>Scale of per reformer</th>
<th>Startup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lanzhou Petrochemical</td>
<td>6.5</td>
<td>2/A</td>
<td>NG 16854 Nm³/h</td>
<td>2004</td>
</tr>
<tr>
<td>2</td>
<td>Inner Mongolia Tianye</td>
<td>6.5</td>
<td>2/A</td>
<td>NG 16854 Nm³/h</td>
<td>2005</td>
</tr>
<tr>
<td>3</td>
<td>Ningxia Baofeng</td>
<td>3.6</td>
<td>1/A</td>
<td>COG 75000 Nm³/h</td>
<td>2014</td>
</tr>
<tr>
<td>4</td>
<td>Shanxi Zhonghui</td>
<td>3.3</td>
<td>1/A</td>
<td>NG 1000 Nm³/h</td>
<td>2016</td>
</tr>
<tr>
<td>5</td>
<td>Xinjiang Tianying</td>
<td>3.35</td>
<td>2/A</td>
<td>NG 12500 Nm³/h</td>
<td>2018</td>
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<tr>
<td>6</td>
<td>Neimeng Jianyuan</td>
<td>3.8</td>
<td>2/A</td>
<td>COG 32250 Nm³/h</td>
<td>2019</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Schedule</td>
</tr>
<tr>
<td>7</td>
<td>Qingdao Sanli</td>
<td>3.6</td>
<td>1/A</td>
<td>LNG+LPG</td>
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<td>8</td>
<td>Xinjiang Zhiben</td>
<td>3.5</td>
<td>2/A</td>
<td>NG 26050 Nm³/h</td>
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<td>9</td>
<td>Xinjiang Guanghui</td>
<td>3.5</td>
<td>2/A</td>
<td>RCOG 180000Nm³/h</td>
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<td>10</td>
<td>Fujian Tianyou</td>
<td>3.6</td>
<td>2/B</td>
<td>Deoiled Pitch</td>
<td>13.75t/h</td>
</tr>
</tbody>
</table>
Coke oven gas NC POX project
Ningxia Baofeng Energy Co., Ltd
COG: 75000Nm3/h
Trains: One
Product: Methanol
Burner: >2 years
High temperature Boiler: >4 years
Start up: 2014
Performance test: March, 2019

The largest scale coke oven gas conversion plant with one train in China
Natural gas NC POX project

Xinjiang Tianying Petrochemical Co., Ltd.

Natural gas: 25000Nm3/h
Trains: 2
Product: Glycol
Start up: June, 2018

<table>
<thead>
<tr>
<th>syngas</th>
<th>v%</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>62.87</td>
</tr>
<tr>
<td>CO</td>
<td>32.28</td>
</tr>
<tr>
<td>CO2</td>
<td>4.17</td>
</tr>
<tr>
<td>CH₄</td>
<td>0.27</td>
</tr>
<tr>
<td>N2</td>
<td>0.41</td>
</tr>
<tr>
<td>H2/CO*</td>
<td>1.95</td>
</tr>
</tbody>
</table>

The first plant conversion natural gas to glycol

* H2/CO=1.95 is the requirement of glycol synthesis by adding a little steam. CO shift plant is not needed.
Coke oven gas NC POX project

Inner Mongolia Jianyuan Coking Co., Ltd.

COG: 64500Nm3/h
Trains: 2
Product: Glycol
Start up: 2019 (plan)

Adjust the ratio of H2 / CO by adding a small amount of CO2 to satisfy the requirement of H2 / CO = ~ 2 for glycol synthesis.
Acknowledgement

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