Biomass Fluidized Bed Gasification for Fuel Gas

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- Introduction of our research team’s study and develop work in coal gasification

- Introduction of the study of this paper
Importance of coal utilization in China

Coal is the main energy in China, this situation will remain in a quite long time. However, coal utilization has brought out many environmental problems.

Coal gasification is one of the most efficient utilization process of clear coal technologies.
Gasification market in China

- Many coal gasification processes in China, but most of them need to be improved.
  - Moving bed---UGI, Lurgi, BGL
  - Fluidized bed---HTW, KRW
  - Entrained flow bed---GE(Texaco), Shell

- Enough market share for every process
- In China, the advanced coal gasification technology should be low investment and operation cost
- It must be suitable for local coal.
Characteristics of Chinese Coal

- 3 Highs

High Ash: ash content: ~ 23 wt.%

High Ash melting point: 50% coal’s FT ≥ 1500°C,

High Sulfur: S ≥ 1 wt.%, ~ 30%, S ≥ 2 wt.%, ~ 15%

Since 1980, ICC, CAS started a series research and development work on “ash agglomerating fluidized bed gasification process” (AFB).
AFB Coal Gasification Process History


small  Process  demonstration  pressurized  pilot  development  plant  development

φ0.3m  φ1.0m  φ2.4m

1t coal/d  24t coal/d  100t coal/d  500 ~ 1000t/d
Ash Agglomerating Fluidized Bed Coal Gasification Process

Pressure : 0.03 MPa
Diameter : 2.4 m
Capacity : 100 t coal/d
Raw gas : ~ 9000 Nm³/h
CO+H₂ content : 68 ~ 72%

for ammonia synthesis of 20,000 t/y

The first demonstration plant of Ash Agglomerating Fluidized Bed coal gasifier

2001, Chengu, Shannxi

ICC, CAS
The first demonstration plant of Pressurized AFB coal gasifier
2008, Shijiazhuang, Hebei

- Pressure: 0.6 MPa
- Diameter: 2.4 m
- Coal: Jinchen Anthracite
- Capacity: 300 t coal/d
- Raw gas: ~27000 Nm³/h
- CO+H₂ content: 68 ~ 72%

for ammonia synthesis of 60,000t/y
Pressure : 0.6 MPa
Diameter : 2.4 m
Coal : Jinchen Anthracite
Capacity : $6 \times 300$ t coal/d
Raw gas : $6 \times 27000$ Nm$^3$/h
CO$+H_2$ content : $68 \sim 72\%$
for methanol synthesis of
300,000 t/y, then to 100,000 t/y gasoline by MTG

The plant of Pressurized AFB coal gasifier for 100,000 t/y gasoline
2009, Jinchen, Shanxi
Pressure : 3.0 MPa
Diameter : 0.8 m
Capacity : 100 t coal/d
CO+H₂ content : 68~72%

We have successfully carried out a 1.5MPa high pressure testing on this semi-industrial platform in 2008.

The pilot plant of Pressurized AFB coal gasifier
2007, Taiyuan, Shanxi
It means that:

the capacity of 1.5 MPa industrial scale unit (with 2.4 meter inside diameter) could be 750 tons of coal daily matched for a middle sized synthesis NH₃ or methanol plants.
Introduction of the study of this paper

- Study background
- Experimental
- Results and discussion
- Conclusion
Study background

- **Biomass is used as energy source and considered as one of the important future energy source**
  - Renewable; Easy to storage and transport

- **Biomass application method**
  - Combustion as fuel → Flue gas to be cleaned costly
  - Fermentation → Residue needs further treatment

- **Biomass gasification**
  - Fluidized bed biomass gasification technology is a better choice
  - Mild operation condition
  - Low investment and operation cost
Study background

Biomass materials

- MBM (meat and bone mixture)
- Poultry litter
- Activated soil

Supplied by a British company EPS (Environment Protection Services)

In several years age, Mad Cow Disease in British was very serious

In order to environmentally treat these biomass waste, to assess the biomass gasification feasibility, the laboratory analysis and experiment of biomass gasification in test scale fluidized bed gasifier was done.
## The analysis of biomass

### Higher volatile (>55%)

**Moderate heating value**

**High ash**

**Low fixed carbon content**

Materials contained energy are easy to volatilize in very short time and further gasified as vapor, leaving only very few carbon-rich materials to be gasified in dense bed of the gasifier. The bed materials may have very high ash content which needs to be withdrawn quickly and the gasifier should be operated under lower temperature to avoid sintering.

<table>
<thead>
<tr>
<th></th>
<th>MBM</th>
<th>Poultry litter</th>
<th>Activated soil</th>
<th>75%MBM + 25%soil (Cal.)</th>
<th>50%MBM + 50%soil (Cal.)</th>
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<tbody>
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<td>Proximate analysis W. %</td>
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<tr>
<td>$M_{ad}$</td>
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<td>Ultimate analysis W. %</td>
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<td>1558</td>
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<td>2672</td>
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<tr>
<td>Kcal/kg</td>
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<td></td>
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</tr>
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<td>Composition of ash W. %</td>
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<td>$\text{SiO}_2$</td>
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<td>0.80</td>
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<td>$\text{Na}_2\text{O}$</td>
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<td>0.92</td>
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<td>Bulk density kg/m$^3$</td>
<td>536</td>
<td>658</td>
<td>760</td>
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</table>
Experimental-weigh loss

Schematic diagram of a modified PerkinElmer TGS-2 thermobalance analyzer

Experimental condition

5mg
<80mesh
Gas flow rate: 100 ml/min
Purge N2 flow rate: 150 ml/min
Temperature: 850-900°C
Atmospheric pressure
60%H2O+ 40%N2

1. gas drying tank 2. vaporizer and preheater 3. SY-01 pump 4. TGS-2 thermobalance 5. quartz tube reactor 6. electrical heater 7. PTC-2 temperature controller 8. balance control unit 9 two-channel recorder
Experimental

Weight loss curve of biomass gasification with steam

All the samples were pyrolysised and gasified at a very high rate (within around several to ten seconds). The weight of samples decreased fast and level off around ten seconds. Among these samples, MBM showed the fastest gasification rate, activated soil showed the lowest rate.
Fluidized bed gasification

Bench-scale fluidized bed gasifier
- Gasifier;
- Cyclone;
- Fuel solid feeding system;
- Ash discharging unit;
- De-dusting System;
- Gasification agents (air) feeding supply;
- Metering equipment

Flow sheet of bench-scale fluidized bed coal gasifier

1. Coal
2. Water
3. 02
4. N2
5. Air
6. Fly ash
7. Condensate
8. Gas outlet
9. Gas analysis
10. Water
11. Gasification agents
12. De-dusting System
13. Metering equipment
14. Gasification agents (air) feeding supply
15. Fuel solid feeding system
16. Ash discharging unit
17. Cyclone
18. Gasifier
19. Bench-scale fluidized bed gasifier
20. Metering equipment
Fluidized bed gasification

Fuel solid feeding system

1-Hopper
2-Gasifier
3-Motor 1
4-Driving band
5-Shaker 1
6-Shaker 2
7-Motor 2
8-Screw feeder
## Results and discussion

### Activated soil gasification

The gas heating value < 200 Kcal/Nm³.

### Poultry litter gasification

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>Biomass feed rate kg/h</td>
<td>2.97</td>
<td>2.97</td>
<td>2.97</td>
<td>2.97</td>
<td>4.01</td>
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<tr>
<td>Air rate Nm³/h</td>
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<td>3.20</td>
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<td>790</td>
<td>783</td>
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<td>786</td>
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<td>1.11</td>
<td>1.25</td>
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<td>1.23</td>
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<td>N2 rate Nm³/h</td>
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<tr>
<td>(dry basis Vol.%)</td>
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<td></td>
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<td></td>
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<tr>
<td>H₂</td>
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<td>8.51</td>
<td>8.17</td>
<td>9.57</td>
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<td>7.62</td>
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<tr>
<td>O₂</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>N₂</td>
<td>62.97</td>
<td>60.37</td>
<td>62.08</td>
<td>62.21</td>
<td>57.61</td>
<td>54.91</td>
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<tr>
<td>CH₄</td>
<td>1.96</td>
<td>2.29</td>
<td>2.41</td>
<td>1.96</td>
<td>2.86</td>
<td>4.64</td>
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<tr>
<td>CO₂</td>
<td>16.38</td>
<td>14.60</td>
<td>13.46</td>
<td>12.06</td>
<td>21.76</td>
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<td>Gas heating value Kcal/Nm³</td>
<td>753.40</td>
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<td>898.25</td>
<td>907.49</td>
<td>811.48</td>
<td>981.75</td>
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<tr>
<td>Gas product yield Nm³/kg</td>
<td>1.57</td>
<td>1.49</td>
<td>1.62</td>
<td>1.57</td>
<td>1.73</td>
<td>1.40</td>
</tr>
</tbody>
</table>

### Gasification temperature:

750~800°C

### Gas heating value:

800~1000 kal/Nm³

### Ratio of air to biomass:

1.1~1.2 Nm³/kg

### Gas product yield:

~ 1.5 Nm³/kg

### H₂:

7~10%

### CO:

10~14%

Test results of poultry litter gasification with air
Results and discussion

**Relationship between air/biomass**
and gas heating value and gas product yield

**Relationship between**
operation temperature and composition of gas

<table>
<thead>
<tr>
<th>Ratio of air and poultry litter</th>
<th>Gas product yield</th>
<th>gas heating value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation temperature</td>
<td>H2, CO</td>
<td>CH4</td>
</tr>
</tbody>
</table>

**Graphs:**
- Gas heat value (Kcal/Nm³) vs. Ratio of air and biomass (Nm³/kg biomass)
- Gas composition (vol.%) vs. Reaction temperature (°C)
- Gas yield (Nm³/kg biomass) vs. Ratio of air and biomass (Nm³/kg biomass)
Results and discussion

Other parameters:

The carbon content of fly fines (captured from gas): 13~18% wt.
The carbon content of discharged ash: 15% wt.
The ratio of fly fines to feeding materials: < 7%

(Absence of selected ash discharge equipment in laboratory gasifier results in higher carbon content in bottom ash thereby causes low carbon conversion)
# Results and discussion

## MBM gasification

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>6</th>
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<tbody>
<tr>
<td>Biomass feed rate kg/h</td>
<td>3.04</td>
<td>3.04</td>
<td>3.04</td>
<td>3.04</td>
<td>4.15</td>
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<tr>
<td>Air rate Nm(^3)/h</td>
<td>3.40</td>
<td>3.30</td>
<td>3.20</td>
<td>3.30</td>
<td>4.50</td>
<td>4.20</td>
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<tr>
<td>Operation temp. °C</td>
<td>755</td>
<td>833</td>
<td>820</td>
<td>828</td>
<td>718</td>
<td>683</td>
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<td>Air/biomass Nm(^3)/kg</td>
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<td>1.13</td>
<td>1.09</td>
<td>1.12</td>
<td>1.12</td>
<td>1.04</td>
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<tr>
<td>N(_2) rate Nm(^3)/h</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>Composition of gas (dry basis Vol.%)</td>
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<td></td>
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<tr>
<td>H(_2)</td>
<td>8.19</td>
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<td>10.03</td>
<td>12.62</td>
<td>8.11</td>
<td>10.01</td>
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<td>N(_2)</td>
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<td>1.40</td>
<td>1.60</td>
<td>1.69</td>
<td>1.48</td>
<td>1.42</td>
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### Test results of MBM gasification with air

- **Gasification temperature:** 750~800°C
- **Gas heating value:** 700~1000 kcal/Nm\(^3\)
- **Ratio of air to biomass:** 1.0~1.1 Nm\(^3\)/kg
- **Gas product yield:** ~ 1.5Nm\(^3\)/kg
- H\(_2\): 7~10%
- CO: 10~14%
Results and discussion

MBM gasification

<table>
<thead>
<tr>
<th>Composition of gas (dry basis Vol.%)</th>
<th>Results of general gas analysis</th>
<th>Results of complete gas analysis</th>
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<tr>
<td>H₂</td>
<td>7.11</td>
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<td>15.18</td>
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<td>C₂H₄</td>
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<td>C₂H₆</td>
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<td>C₃H₆</td>
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<td>0.07</td>
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<td>&gt; C₄</td>
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<tr>
<td>Gas heating value Kcal/Nm³</td>
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Ordinary gas analysis (H₂,N₂,O₂,CO,CH₄,CO₂) could not show real composition of synthesis gas because there existed some C₂H₄,C₂H₆,C₃H₆ and other unknown gas (the part accounts for about 2%(vol) due to the higher volatile in MBM. the real synthesis gas heating value is higher than analysis value about 300Kcal/Nm³

Comparison between general and complete gas analysis
Conclusion

- It is feasible for biomass including poultry litter, MBM being gasified with fluidized bed technology. Laboratory test results show that these biomasses can be used to produce fuel gas.

- All biomasses are pyrolysised and gasified at a very high rate (within around several to ten seconds). Among these samples, MBM showed the fastest gasification rate, activated soil showed the lowest rate.
The operation temperature of all biomass gasification in fluidized bed gasifier are around 700~800°C. The ratio of air to biomass is perhaps the most important factor in biomass gasification with air. In practice, it defines the temperature of the bed, the gas heating value and the gas product yield.

**Operation parameters:**

The operation temperature of all biomass gasification in fluidized bed gasifier are around 700~800°C. The ratio of air to biomass is perhaps the most important factor in biomass gasification with air. In practice, it defines the temperature of the bed, the gas heating value and the gas product yield.

**Conclusion**

**Operation parameters:**

- **Gas heating value:**
  - **Poultry litter:** 700~1000 kal/Nm³
  - **MBM:** 800~1000 kal/Nm³

- **Ratio of air to biomass:**
  - **Poultry litter:** 1.0~1.1 Nm³/kg
  - **MBM:** 1.1~1.2 Nm³/kg

- **Gas product yield:**
  - **Poultry litter:** ~ 1.5Nm³/kg
  - **MBM:** ~ 1.5Nm³/kg