SUITABILITY OF FEEDSTOCKS FOR THE SASOL-LURGI FIXED BED DRY BOTTOM GASIFICATION PROCESS

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Contributions by :
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COAL TO SYNGAS...BACKGROUND

• Coal used as main feedstock to produce Syngas via Sasol-Lurgi FBDB Gasification
• South African plants gasify ±30 M tons of coal to Syngas
• 97 FBDB Gasifiers…17 Sasolburg and 80 in Secunda
• Production rates in excess of design capacity…

CONTINUOUS IMPROVEMENT
OVERVIEW ON COAL PROPERTIES

Bituminous to sub-bituminous coal

Low rank, inertinite rich \( (\text{RoV } 0.5-0.7) \)

High ash content \( (19-35\% \text{ air dry basis}) \)

Moderate reactivity

No beneficiation

Minimum preparation
CHARACTERISTICS OF FBDB GASIFIERS

**Advantages**
- Lump coal and limited grinding
- High ash content
- Coal with high ash flow temperature
- Valuable co-products (e.g. tars)

**Limitations**
- Limited ability to handle excessive fine coal
- Broad PSD can lead to coal segregation and channel burning
- Pressure drop can limit gas throughput
COAL MINING AT SASOL

Sasolburg (1 underground and 1 strip mine)

Secunda (5 underground and 1 strip mine)

Total production

1954-1964 → 20 M tons

2000 → 50.9 M tons/ annum
COAL CHARACTERISTICS AND THE EFFECT ON GASIFIER PERFORMANCE

Moisture, ash, fixed C and volatiles (Proximate analysis)
Total C and S content (Ultimate analysis)
CO₂ reactivity

**Particle size distribution**

**Ash melting properties and ash composition**

**Caking properties** under 26 bar pressure

**Thermal** and mechanical **fragmentation**

Fischer Assay

Heating value

Maceral analysis and rank
ASH ANALYSIS

Coal sources

% Ash (average - air dried basis)

Secunda | Sasolburg | Non South-African | Biological sludge
PARTICLE SIZE DISTRIBUTION

Described by the Ergun Equation:

\[
\frac{\Delta P}{L} = 150 \frac{(1 - \varepsilon)^2 \mu U_s}{\varepsilon^3 d_p^2} + 1.75 \frac{(1 - \varepsilon) \rho U_s^2}{\varepsilon^3 d_p}
\]

\(\varepsilon = \text{Bed Voidage}\)
\(\mu = \text{Viscosity}\)
\(\rho = \text{Fluid Density}\)
\(U_s = \text{Superficial Velocity}\)
\(d_p = \text{Particle Diameter}\)
PARTICLE SIZE DISTRIBUTION (cont.)

Average particle size refer to as “Sauter diameter - Fluidization Engineering, Kunii, D. and Levenspiel, O., 1977

\[ d_p = \bar{d}_p \phi \]

\[ \bar{d}_p = \frac{1}{\sum_{1-i} \left( \frac{x_i}{d_{p,i}} \right) } \]
## PARTICLE SIZE DISTRIBUTION (cont.)

<table>
<thead>
<tr>
<th>Fraction (mm)</th>
<th>A Typical composition</th>
<th>Coarser fraction</th>
<th>Finer fraction</th>
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<tr>
<td>-19+13.2</td>
<td>42.1</td>
<td>52.1</td>
<td>42.1</td>
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<tr>
<td>-13.2+9.5</td>
<td>33.3</td>
<td>23.3</td>
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<tr>
<td>-9.5+6.7</td>
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<td>24.6</td>
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<td>Sauter diameter</td>
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<td>% Change</td>
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<td>3</td>
<td>7.1</td>
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</table>
THERMAL FRAGMENTATION

- Primary and secondary fragmentation can occur when exposed to high temperatures

- Procedure to determine thermal fragmentation
  Van Dyk, J.C., Fuel 80 (2001), pp. 245-249

\[
\text{% Thermal fragmentation} = \frac{\overline{d}_p \text{ before test} - \overline{d}_p \text{ after test}}{\overline{d}_p \text{ before test}} \times 100
\]

- Moisture contributes >75% to thermal fragmentation

- Weathering/oxidation
### LINEAR CORRELATIONS \( (r_{xy}) \)

<table>
<thead>
<tr>
<th>Analysis used for model</th>
<th>Coal characteristic used in regression equation (independent variable)</th>
<th>( r ) (correlation coefficient)</th>
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<tr>
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<tr>
<td></td>
<td>Inertinite</td>
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<td>Maceral rock types</td>
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<td>Vitrinertite</td>
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<td></td>
<td>Trimas</td>
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<td></td>
<td>Vitrite</td>
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</table>

- **Proximate analyses Moisture (air dry):** 0.72
- Oxidation 0.53
- Ash properties
  - \( \text{Na}_2\text{O} \) 0.65
  - Melting temperatures -0.2
### MULTIPLE REGRESSION (stepwise forward method)

<table>
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<th>Analysis used for model</th>
<th>$r$ (correlation coefficient)</th>
<th>Coal characteristic used in $p$-value regression equation (independent variable)</th>
<th>$p$-value</th>
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<td>Microlithotypes and oxidation</td>
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<td>Oxidation</td>
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</table>
THERMAL FRAGMENTATION (cont.)

% Thermal fragmentation

Coal sources

Secunda

Sasolburg

% Thermal fragmentation (dry)

% Thermal fragmentation (wet)
CAKING

SOFTENING / PLASTICITY PROPERTY OF COAL, WHICH CAUSES PARTICLES TO MELT OR SINTER TOGETHER TO FORM LARGER PARTICLES WHEN HEATED

• In-house method to determine caking propensity
  (coal sample with predetermined PSD, inert atmosphere, typical gasifier pressure)
• Pressure influences caking propensity
• Atmosphere does not have a significant effect on caking propensity
COMPARISON OF CAKING PROPERTIES

Coal sources

% Caking

0 10 20 30 40 50 60 70 80 90 100

Safe operating region

Uncertain area

High risk

Secunda

Sasolburg

Non South-African

Coal sources
ASH FUSION TEMPERATURE AND COMPOSITION

- Indication of ash agglomeration / clinkering
- Ideal operation between initial deformation temperature and ash melting temperature
ASH FUSION TEMPERATURE AND COMPOSITION (cont.)

• Current coal sources used by Sasol
  • Initial deformation temperature > 1250°C
  • Flow temperature > 1300°C

• Ca and Fe content indicate ash fusion behavior

• BUT, Fe in a specific phase can slag <800°C and solidify again

Is the standard AFT analysis the best indication of ash fusion behavior?

Currently under investigation by Sasol Technology, R&D
MAXIMUM THEORETICAL PURE GAS YIELD CALCULATION

RESULTS GIVEN IN THIS SECTION MUST BE SEEN AS A QUALITATIVE TOOL AND NOT AS A QUANTITATIVE COMPARISON WITH PLANT DATA

- Experimental results
  (pyrolysis conditions up to 600 °C under 26 bar and inert atmosphere)
- Thermodynamic model
MAXIMUM THEORETICAL PURE GAS YIELD CALCULATION (cont.)

TYPICAL EXPERIMENTAL RESULTS

Typical Experimental Results

Pure Gas Yield (m³/t DAF)

Coal sources
CONCLUSIONS

*Interpretation* of standard coal analyses and uniquely developed laboratory tests

+ *experience* gained by Sasol over the past 50 years

→ *identify suitable coal sources for SasoLurgi FDBD gasification*

→ *indication of expected gasifier performance*
CONCLUSIONS (cont.)

- Also have the ability to test coal on an isolated commercial scale Sasol-Lurgi MK IV test gasifier
  - ± 4000 tons of test coal
  - 6 day test run at coal feed rate of ± 50 tons/h

- Full scale test results are supportive of laboratory scale coal characterization data. Gasifier performance dependant on the combined effect of all properties due to the large degree of interaction.