THE QUALITY OF SYNGAS PRODUCED BY FLUIDISED BED GASIFICATION USING SUNFLOWER HUSK

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ABSTRACT

Gasification systems are successfully applied to the production of energy from biomass. In the present work, the effects of some parameters like excess air ratio and temperature on the quality and the composition of syngas produced in a fluidised bed gasifier using sunflower husks as fuel were investigated. The syngas composition for sunflower husk with an excess air ratio of 0.09 was about 39.62%, 43.39%, 0.3%, 0.5%, 15.41 for H₂, CO, CH₄, CO₂, N₂, respectively, in a moisture free basis. In this paper, the lower heating value of the syngas is reported as an indicator of the gas quality. The lower heating value of the syngas produced by sunflower husk was calculated from the concentration of the combustible components and it ranges from 6.7 MJ/Nm³ to 9.8 MJ/Nm³. The LHV of syngas produced decreased with excess air ratio. It has been found that the highest gas quality occurs at the lowest excess air ratio and at operating temperatures around 900°C.

KEYWORDS: syngas quality, sunflower husk, gasification, excess air ratio, LHV

1. INTRODUCTION

Gasification is a thermo-chemical process of gaseous fuel production by partial oxidation of a solid fuel [1]. Coal gasification has been widely used to harness energy from coal in a more environmentally benign fashion. Biomass is indeed nothing but young coal and can be featured as an alternative to coal. Gasification systems are successfully applied to the production of energy from biomass. Renewable energy sources mitigate greenhouse gas emission because CO₂ emitted from thermal conversion is naturally sequestered by photosynthesis. Biomass use as an energy resource relieves municipal and agricultural waste management from the burden of voluminous waste [2].

Thermochemical gasification of biomass is a well-known technology that can be classified depending on the gasifying agent: air, steam, steam–oxygen, air–steam, O₂-enriched air [3].

A wide range of biomass sources, such as traditional agricultural crops, dedicated energy crops, residues from agriculture and forestry as well as organic wastes can be gasified [4].

Fluidised bed gasification was originally developed to overcome operational problems of fixed bed gasification related to fuels with high ash content and to increase the efficiency of gasification process [5].

In fluidised bed gasifiers, biomass particles undergo drying, pyrolysis and gasification in a hot, fluidised mixture with inert bed material and air. The fluidised bed process enables good heat transfer between the gas and solid phases [6].

Fluidised bed reactors are gasifiers without different reaction zones. They have an isothermal bed operating at temperatures usually around 700–900°C, lower than maximum fixed bed gasifiers temperatures [7]. There are bubbling fluidised bed (BFB) and circulating fluidised bed (CFB) gasifiers. Circulating fluidised bed gasifiers employ more turbulent mixing than bubbling fluidised bed systems, and use cyclones to separate solid particles from the gas stream before returning them to the bottom of the riser section [6].

The objective of the present paper is to investigate the effects of some parameters like excess air ratio and temperature on the quality and the composition of syngas produced in a fluidised bed gasifier using sunflower husks as fuel. It has been
found that the highest gas quality occurs at the lowest excess air ratio and at operating temperatures around 900°C. The syngas composition and heating value were found to be similar to those reported by other researchers [8], [2], [9].

![Bubbling fluidised bed gasifier](image1)

**Fig. 1. Bubbling fluidised bed gasifier [7]**

### 2. METHODOLOGY

Air gasification experiments were carried out in a fluidised bed gasifier.

The biomass material used in this experiment was sunflower husk. The agent gasification used was air.

The proximate and ultimate analyses of sunflower husk are presented in Table 2.

The gasifying agent utilised in the fluidised bed gasifier has a big influence on the quality of syngas produced. This agent influences the heating value and the composition of syngas (Table 1).

**Table 1. The influence of the gasifying agent on the syngas quality produced by gasification process [10].**

<table>
<thead>
<tr>
<th>Gasifying agent</th>
<th>Air</th>
<th>H₂O</th>
<th>O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating value (MJ/Nm³)</td>
<td>4-6</td>
<td>10-15</td>
<td>8-14</td>
</tr>
</tbody>
</table>

**Table 2. Proximate and ultimate analysis of sunflower husk**

<table>
<thead>
<tr>
<th>Fuel sample</th>
<th>Sunflower husk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate analysis (% of dry fuel with ash)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>49.11</td>
</tr>
<tr>
<td>H</td>
<td>5.9</td>
</tr>
<tr>
<td>N</td>
<td>0.70</td>
</tr>
<tr>
<td>O</td>
<td>40.57</td>
</tr>
<tr>
<td>A</td>
<td>3.71</td>
</tr>
<tr>
<td>Proximate analysis (% of fuel with initial moisture)</td>
<td></td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>17.00</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>65.79</td>
</tr>
<tr>
<td>Ash</td>
<td>3.71</td>
</tr>
<tr>
<td>Moisture</td>
<td>13.50</td>
</tr>
</tbody>
</table>

In this paper, the lower heating value of the syngas is reported as an indicator of the gas quality.

The lower heating value of syngas is dependent on the percentage quantities of CO, H₂ and CH₄ in producer gas and can be calculated from the following equation:

\[ LHV_g = Y_{CO}LHV_{CO} + Y_{H_2}LHV_{H_2} + Y_{CH_4}LHV_{CH_4} \]

where \( Y \) is the mole fraction of each gas species. The lower heating values of the gas species are:

\[ LHV_{CO} = 13.1 \text{ MJ/Nm}^3, \]
\[ LHV_{H_2} = 11.2 \text{ MJ/Nm}^3, \]
\[ LHV_{CH_4} = 37.1 \text{ MJ/Nm}^3 \] [11].

### 3. RESULTS AND DISCUSSION

The influence of varying excess air ratio on syngas composition and syngas heating value was investigated.

The effects of excess air ratio on product gas composition produced by sunflower husk are illustrated in Table 1 and Fig. 3.

The main components of the syngas produced are CO, H₂, N₂, CO₂, H₂O and CH₄.

The increase of the excess air ratio causes a linearly increase of the N₂ molar fraction due to the greater amount of air fed to the fluidised bed gasifier.

The molar fraction of CH₄ is very low and this increases with the increase of the excess air ratio. The highest concentration of CH₄ was obtained for gasification of sunflower husk at an excess air ratio of 0.23.

It can be observed that the increase in excess air ratio increases the CO₂ content in the syngas. On the other hand, when the excess air ratio is increased, the molar fraction of CO in the syngas decreases. The highest content of CO in the syngas was obtained by gasification of sunflower husk for an excess air ratio of \( \lambda = 0.09 \). The molar fraction of CO is the most significant contribution to the syngas heating value.
The highest content of the H\textsubscript{2} in the syngas was obtained by gasification of sunflower husk for an excess air ratio $\lambda=0.09$ and the minimum value for an excess air ratio $\lambda=0.23$. The molar fraction of H\textsubscript{2} has an important contribution in the calculating of syngas heating content.

Table 1. The molar composition of syngas produced by gasification of sunflower husk

<table>
<thead>
<tr>
<th>Temperature</th>
<th>$\lambda$</th>
<th>CO\textsubscript{2}</th>
<th>CO</th>
<th>H\textsubscript{2}</th>
<th>CH\textsubscript{4}</th>
<th>N\textsubscript{2}</th>
<th>NH\textsubscript{3}</th>
<th>H\textsubbox{2}O</th>
<th>LHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>0.22406</td>
<td>0.076</td>
<td>0.276</td>
<td>0.2692</td>
<td>0.0093</td>
<td>0.3223</td>
<td>0.0013</td>
<td>0.0458</td>
<td>6.72087</td>
</tr>
<tr>
<td>725</td>
<td>0.18556</td>
<td>0.0582</td>
<td>0.3146</td>
<td>0.2972</td>
<td>0.0086</td>
<td>0.2821</td>
<td>0.0014</td>
<td>0.0378</td>
<td>7.48507</td>
</tr>
<tr>
<td>750</td>
<td>0.15535</td>
<td>0.043</td>
<td>0.3479</td>
<td>0.3223</td>
<td>0.0077</td>
<td>0.2472</td>
<td>0.0015</td>
<td>0.0304</td>
<td>8.14393</td>
</tr>
<tr>
<td>775</td>
<td>0.13262</td>
<td>0.031</td>
<td>0.3748</td>
<td>0.3435</td>
<td>0.0068</td>
<td>0.2186</td>
<td>0.0015</td>
<td>0.0238</td>
<td>8.67993</td>
</tr>
<tr>
<td>800</td>
<td>0.11612</td>
<td>0.0219</td>
<td>0.3953</td>
<td>0.3605</td>
<td>0.0059</td>
<td>0.1965</td>
<td>0.0016</td>
<td>0.0183</td>
<td>9.08985</td>
</tr>
<tr>
<td>825</td>
<td>0.10444</td>
<td>0.0153</td>
<td>0.4104</td>
<td>0.3737</td>
<td>0.005</td>
<td>0.1801</td>
<td>0.0016</td>
<td>0.014</td>
<td>9.39061</td>
</tr>
<tr>
<td>850</td>
<td>0.09632</td>
<td>0.0106</td>
<td>0.4211</td>
<td>0.3835</td>
<td>0.0042</td>
<td>0.1683</td>
<td>0.0016</td>
<td>0.0106</td>
<td>9.602741</td>
</tr>
<tr>
<td>875</td>
<td>0.09073</td>
<td>0.0074</td>
<td>0.4286</td>
<td>0.3908</td>
<td>0.0036</td>
<td>0.1599</td>
<td>0.0016</td>
<td>0.008</td>
<td>9.75467</td>
</tr>
<tr>
<td>900</td>
<td>0.08688</td>
<td>0.0052</td>
<td>0.4339</td>
<td>0.3962</td>
<td>0.003</td>
<td>0.1541</td>
<td>0.0016</td>
<td>0.006</td>
<td>9.85833</td>
</tr>
</tbody>
</table>

Fig. 3. The influence of the excess air ratio on the syngas composition for sunflower husk

It has been found that the syngas composition for sunflower husk with an excess air ratio of 0.09 was about 39.62%, 43.39%, 0.3%, 0.5%, 15.41 for H\textsubscript{2}, CO, CH\textsubscript{4}, CO\textsubscript{2}, N\textsubscript{2}, respectively, in a moisture free basis.

The gasification temperature plays an important role in biomass gasification process. In the present work, gasification temperature was varied from 700 to 900°C in 25°C.

The gasification temperature depends on the amount of air fed to the gasifier being controlled by the excess air ratio.

Figure 5 shows that the excess air ratio decreases with the gasification temperature.

Fig. 4. The excess air ratio as a function of temperature
The useful energy content in the syngas can be quantified by the syngas heating value. Fig. 5 shows the variation of lower heating value against the excess air ratio. It is evident that the lower heating value decreases with the increase in excess air ratio. The lower heating value of the syngas produced by sunflower husk was calculated from the concentration of the combustible components. The LHV of the producer gases ranges from 6.7 MJ/Nm³ to 9.8 MJ/Nm³.

The LHV is high for low excess air ratios due to the high H₂ and CO contents.

5. CONCLUSIONS

In the present work, the gasification of sunflower husk in a fluidised bed gasifier was investigated. The air was used as the biomass gasification agent to explore the effects of some critical parameters on gasification performance.

The syngas composition for sunflower husk with an excess air ratio of 0.09 was about 39.62%, 43.39%, 0.3%, 0.5%, 15.41 for H₂, CO, CH₄, CO₂, N₂, respectively, in a moisture free basis.

In this paper, the lower heating value of the syngas is reported as an indicator of the gas quality. The lower heating value of the syngas produced by sunflower husk was calculated from the concentration of the combustible components and it ranges from 6.7 MJ/Nm³ to 9.8 MJ/Nm³. It has been found that the highest gas quality occurs at the lowest excess air ratio and at operating temperatures around 900°C.

Acknowledgements

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