Effect of Size of Feedstock on Specific Gasification Rate, Calorific Value of Producer Gas and Gasifier Efficiency

A. Bhaumik Sheth, B. R.N.Patel

Abstract—High prices of oil and natural gas are leading to an increased interest in "Energy Conservation" technologies such as biomass gasification, meth nation, liquid faction and solidification. Heating systems based on wood, fuel, electricity, coal/lignite are common in some industries. Environmental pollution, poor process control and cost are some of the limitation of these systems. On the other hand biomass gasifier technology offers good efficiency, process controllability, economic viability and environmental accessibility. However efficiency and viability of these process is biomass specific. In view of these, it is planned to assess the effect of particle size of fuel on specific gasification rate, calorific value and efficiency. For this purpose wood has been selected as biomass. Nine different sizes of wood materials are selected. The length of the wood is taken as 25 mm, 50 mm and 75 mm where as diameter of wood ranges from 20-25 mm, 25-50 mm and 30-35 mm. It is observed that moisture content, TAR concentration, calorific value, efficiency etc. is highly dependent on feed stock shape and size. It is observed that wood with 50 mm length and 25-30 mm diameter offers maximum efficiency along with higher calorific value.

Key-words: Biomass Gasifier, Downdraught Gasifier, Calorific Value, Gasifier efficiency.

I. INTRODUCTION

Up and downdraught gasifiers are limited in the range of fuel size acceptable in the feed stock. Fine grained and/or fluffy feed stock may cause flow problems in the bunker section of the gasifier as well as an inadmissible pressure drop over the reduction zone and a high proportion of dust in the gas [1-3]. Large pressure drops will lead to reduction of the gas load of downdraught equipment, resulting in low temperatures and tar production. Excessively large sizes of particles or pieces give rise to reduced reactivity of the fuel, resulting in startup problems and poor gas quality, and to transport problems through the equipment. A large range in size distribution of the feedstock will generally aggravate the above phenomena [4-5]. Too large particle sizes can cause gas channeling problems, especially in up draught gasifiers. Acceptable fuel sizes for gasification systems depend to a certain extent on the design of the units [6-7]. In general, wood gasifiers operate on wood blocks and woodchips ranging from 80 x 40 x 40 mm. to 10 x 5 x 5 mm. Charcoal gasifiers are generally fuelled by charcoal lumps ranging between 10 x 10 x 10 mm. and 30 x 30 x 30 mm. Fluidized bed gasifiers are normally able to handle fuels with particle diameters varying between 0.1 and 20 mm.

II EXPERIMENTAL SETUP

Fig. 1. Schematic of Experimental Set up

III MATERIAL AND METHODS

i) Conducting proximate analysis

The proximate analysis involves by using simple test methods, estimating the main constituents of biomass which have a direct influence on the combustion characteristics, e.g. the moisture content of a biomass sample, the amount of volatiles, fixed carbon and the amount of ash. All these components of the proximate analysis are related to some way to the combustion characteristics of the biomass.

Moisture content

The moisture content of biomass can be estimated by taking a small pre-weight sample. The sample with an initial mass of Mi is placed in drying oven in which a temperature of 110°C is maintained. After 2 hours the mass is noted as Me. The moisture content of biomass can be calculated as:

\[ [M] = \frac{M_i - M_e}{M_i} \times 100 \]

Volatiles Matter

The volatile matter of biomass is that component of the carbon present in the biomass, which, when heated, converts to the vapour. In almost all types of biomass the amount of volatile matter which is a function of the carbon to hydrogen ratio is high and will be about 70-80% of the weight of dry biomass. The amount of volatile matter is determined by heating a dried ground sample of biomass with an initial mass Mi in a closed crucible in an oven with a temperature of 600°C for six minutes followed by heating the sample in an oven with the temperature of 900°C for another six minutes and then its weight (Mf) is measured.
\[ [V] = \frac{M_i - M_f}{M_i} \times 100 \]

**Ash content**

Ash is the noncombustible component of the biomass. The higher the amount of ash in a fuel, the lower is the calorific value of the fuel. The amount of ash is determined by heating a dry sample of biomass in a crucible in a furnace which is kept at 900°C for 15 minutes so that all fuel is burnt completely. Sample is taken out of the furnace and the residue remaining in the crucible is ash. Measure the weight of the ash \( (M_s) \). percentage ash content \([a]\) is given by

\[ [a] = \frac{M_s}{M_i} \times 100 \]

**Fixed carbon**

The final step in proximate analysis is the determination of the amount of the fixed carbon \([c]\) by using mass balance calculations. The amount of fixed carbon,

\[ [c] = 100 - (M + a + V) \]

**ii) Calorific value of feed stock**

The calorific value of a fuel is defined as the amount of heat evolved when a unit weight of fuel is completely burned and the combustion products such as CO2 and H2O are cooled of 298 K. It is usually expressed in kilo joules. The calorific value of any given species of biomass is dependant on the moisture content and its density. The calorific value is determined by a bomb calorimeter. A sample of air dried biomass with a known mass is burnt in an atmosphere of oxygen in a stainless steel high pressure vessel. known as a bomb. The bomb is a placed in a calorimeter which is highly polished outer vessel containing a known amount of water with a known temperature. The combustion products CO2 and H2O are allowed to cool to the standard temperature. The resulting heat of combustion is measured from the accurate measurement of the rise in the temperature of water in the calorimeter, the calorimeter itself and the bomb. The calorific value so estimated is the gross calorific value.

**III RESULT AND DISCUSSION**

Experiment were conducted on 60 KWe downdraft gasifier of SPRERI, V.V.Nagar with 9 different sizes of feedstock to check the effect of size of feedstock on specific gasification rate, calorific value of producer gas and efficiency of gasifier. The methods and instruments/equipments used to measure different fuel properties discussed earlier. Following table shows the size of feedstock of wood used for experiments.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Length (mm)</th>
<th>Diameter (mm)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>20-25</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>25-30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>30-35</td>
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<td>7</td>
<td>20-25</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>25-30</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>30-35</td>
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</tr>
</tbody>
</table>

**i) Experiment methodology**

Experiments were conducted with each of the as a feed material shown in above table. In 60 kW downdraft gasifier is initially filled with 20 kg char of the same biomass. Then dry leaves are feed over the char up to the level of air tiers. Then wood having specific length and diameter as mention in table. is fed in the biomass gasifier. Starting blower of capacity 1.5 HP is initially put in operation then the biomass material in gasifier is fired. Approximately after 10 minute the producer gas show generated burns in the starting blower. Then main blower of capacity 5 HP is switched on. The producer gas is then burned in the main burner. After 10 minutes the pressure drop across the cyclone, pressure drop at orifice is measured at an interval of 10 minutes. Thermocouples are installed in the biomass gasifier at pyrolysis, oxidation and reduction zone is measured at a interval of 10 minutes. Temperature of producer gas is also measure at gas outlet before cyclone and at orifice. Surface temperature of the gasifier and flame temperature has also been measured. TAR sample is collected at orifice for TAR and SPM measurement. Producer gas sample at orifice is collected by displacement of water and same is analyzed with help of gas chormo graph for composition of producer gas and calorific value of gas.

**ii) Temperature profile at pyrolysis, oxidation and reduction zone**

As discussed in earlier section temperatures at pyrolysis, oxidation and reduction zone were taken at an interval of 10 minutes for every sample.

Fig. 2 to Fig.4 indicate the temperature at said zones at 20 minute, 30 minute and 40 minutes respectively.
As accepted the temperature at pyrolysis zone in each case as in the range of 200°C to 400°C, temperature in the oxidation zone is in the range of 800°C to 1100°C, while same in reduction zone is in the range of 600°C to 800°C as reported in literature. It is observed from the temperature profiles at pyrolysis, oxidation and reduction zone at interval of 20 minute, 30 minute and 40 minute after firing the gasifier for different feedstock that the temperature for wood having 75 mm length and diameter in the range of 25-30 mm and 30-35 mm is not within the temperature range of the said zones mentioned as earlier. It is observed that the highest temperature in oxidation zone is reported for wood sample, having 50 mm length and 20-25 mm and 25-30 mm diameter in all three cases (20 minute, 30 minute and 40 minutes).

From the temperature profile as shown in Fig. 2, Fig. 3 and Fig. 4, it is clear that 50 mm length and 25-30 mm diameter is preferred feedstock.

iii) Gas temperature
Producer gas temperature is measured at gas outlet of gasifier before the cyclone and at the orifice is measured at a interval of 10 minute. Fig.5, Fig. 6 and Fig. 7 indicate the gas temperature at this location respectively. It is seen that the gas temperature before cyclone for most of the feedstock is in the range of the 550°C to 650°C and at orifice the same in the range of the 275°C to 325°C except for the feedstock having length 75 mm and diameter 30-35 mm.

iv) Moisture, TAR and SPM concentration in producer gas
Fig.8 and Fig. 9 indicates moisture content and TAR and SPM in producer gas for different fuels at required interval of 10 minutes. It is seen that moisture content is higher in the sample of 25 mm lengths in comparison to other models. TAR and SPM Concentration in the producer gas increases with moisture content in the fuel. It can be observed from
Fig. 9 that SPM concentration for feed stock sample having 50 mm length and 20-25 mm and 25-30 mm diameter does not change significantly with time. The concentration is moderate with respect to most of the other samples.

Experiments were performed on 60 KWe downdraft gasifier. Literature suggest that the fuel consumption for 60 KWe gasifier is typically 60 kg/h. Fig. 10 indicates the fuel consumption rate in gasifier at 30 minutes and 60 minutes after firing of the gasifier. It is observed that the fuel consumption for 50 mm length and 20-25 mm and 25-30 mm diameter. All samples having 25 mm length in line with rated fuel consumption 60 kg/h. Fuel consumption of the order of 50 to 55 kg/h for all the samples having 25 mm length.

Temperature of producer gas is recorded while measuring flow rate at orifice to normalize flow rate at standard condition. Fig. 11 indicates the flow rate of producer gas for different feedstock. It is evident from the figure that except feedstock with 25 mm length and 25-30 mm diameter the gas flow rate more or less same for most of the feedstock samples.

Gas samples were collected at orifice at an interval of 10 minutes after 20 minutes of starting the main blower. These samples were analyzed for gas composition. It is observed from the Fig 12 that the calorific value is maximum for sample having 50 mm length and 25-30 mm diameter. Lower calorific value producer gas is obtained with fuel having 75 mm length and 20-25 mm and 30-35 mm diameter. It is observed that better efficiency (Fig. 13) obtain with the fuel having size 25 mm and 50 mm length. Efficiency is poor with 75 mm length. The poor efficiency with 75 mm length is attributed to lower fuel consumption and less calorific value of producer gas and high moisture content.

The summary of the above discussion is given in table. From the table it is clear that looking to the parameters calorific value of producer gas, efficiency and feedstock consumption, the feedstock with 50 mm length and 25-30 mm diameter is the best with this size. The calorific value of producer gas is observed that 4981 KJ/m³ with 57 % Moisture content is also least in this sample with in comparison to all other samples.
IV CONCLUSION

Following are the major condition on the basis of above study. Typical fuel consumption for 60 KWe downdraft gasifier is approximate 60 kg/h for 50 mm length and 25-30 mm diameter fuel constant varies with the size of feedstock.

- Typical fuel consumption for 60 KWe downdraft gasifier is approximate 60 kg/h for 50 mm length and 25-30 mm diameter fuel constant varies with the size of feedstock.
- Gas analysis of producer gas with different feedstock indicates that calorific value of producer gas varies between 778kcal/m3 to 1190kcal/m3.
- Calorific value was observed highest with feedstock of 50 mm length and 25-30 mm diameter, 75 mm length and 30-35 mm diameter gave producer gas with lowest Calorific value.
- The flow rate of the producer gas at orifice at given gas temperature was observed almost constant at 250 m3/h.
- The moisture content in producer gas was observed lowest for 50 mm length and 25-30 mm diameter. Some were higher with the entire feed stock sample with 75 mm length.
- The general conclusion from the above study is that the 50 mm length and 25-30 mm diameter of feedstock is the best feedstock among all the selected feedstock for the present study.

<table>
<thead>
<tr>
<th>Length</th>
<th>25 mm</th>
<th>50 mm</th>
<th>75 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (mg/m3)</td>
<td>6034</td>
<td>4961.6</td>
<td>9549</td>
</tr>
<tr>
<td>TAR and SPM (mg/m3)</td>
<td>136.4</td>
<td>144.68</td>
<td>178.78</td>
</tr>
<tr>
<td>Fuel Consumption (kg/hr)</td>
<td>54.05</td>
<td>49.8</td>
<td>51.274</td>
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<tr>
<td>Flow rate (m3/hr)</td>
<td>250.3</td>
<td>248.96</td>
<td>253.87</td>
</tr>
<tr>
<td>Flow rate (Nm3/hr)</td>
<td>118.71</td>
<td>131.39</td>
<td>123.48</td>
</tr>
<tr>
<td>CV of gas (kcal/m3)</td>
<td>1047.9</td>
<td>897.56</td>
<td>1025.3</td>
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<tr>
<td>Efficiency (%)</td>
<td>55.13</td>
<td>56.73</td>
<td>59.15</td>
</tr>
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</table>

TABLE II

COMPARISON OF FUEL CONSUMPTION, GAS FLOW RATE, CALORIFIC VALUE EFFICIENCY FOR DIFFERENT FEEDSTOCK

References