Biomass air gasification in fixed bed gasifiers

This chapter is a theoretical orientation towards understanding the biomass thermo-chemical conversion to energy via gasification. Biomass gasification process, gasifier types, gasifier fuel properties are discussed. The chapter begins with a brief historical introduction on evolution of gasification technology. The process of gasification is very complex one and there are various types of gasifiers which are in use for different purposes. The discussion is restricted to biomass air gasification in fixed bed gasifiers only.

2.1 Introduction:

The chemical energy of biomass can be converted to useful forms through biochemical, chemical and thermo-chemical conversion methods. Only selected biomass can be converted into biogas, ethanol, biodiesel etc. through biochemical and chemical methods, whereas most of the biomass material can undergo thermo-chemical conversion, thus making this method much more attractive than others (Chopra and Jain, 2007). Amongst the thermo-chemical conversion technologies biomass gasification has attracted the highest interest as it offers higher efficiencies in relation to combustion. Gasification is a partial oxidation process at elevated temperatures (500-1400 °C) that results in producer gas. Gasification is carried out both in fixed bed and fluidized beds. The fixed bed gasifiers are suitable for small-scale applications (<10 MW) and the fluidized bed configurations are cost effective in large-scale applications that generate over 15 MW.

2.2 History of gasification:

Gasification, a thermo-chemical conversion process, has been exploited for more than a century for converting solid feedstock to gaseous energy carriers (Bauen, 2004). The first gasifier patent was issued in England at the end of the 18th century and producer gas from coal was mainly used as lighting fuel throughout the 19th century. The first commercial up-draft gasifier for continuous gasification of solid fuels with air was installed in 1839. Up-draft gasifiers were subsequently further developed for
different fuels and were in widespread use in specific industrial power and heat applications up to the 1920's, when their function was gradually taken over by oil fuelled engines and furnaces. In anticipation of unreliable petroleum supply, between 1920 and 1940, compact tar-free down-draught gasifier systems for automotive application were developed in Europe. During the 2nd World War, tens of thousands of those gasifiers were used in Europe and elsewhere. Shortly after the War, most gasifiers were decommissioned because of widespread availability of inexpensive liquid fuels.

The energy crisis of the 1970's brought a renewed interest in biomass gasification. A few developing countries including Philippines, Indonesia, Brazil and India started gasifier implementation programmes based on locally developed technologies. India is a leading country in the world both in terms of biomass gasifier research and development activities as well as their applications and dissemination.

![Fig. 2.1 Car powered by Biomass Gasifier during World War-II (Source: Internet)](image)

2.3 Biomass and Gasification:

In biomass gasification process, biomass is used as feedstock. There are different forms of biomass with different compositions. The gasification process and the design of the reactor are influenced by the physical, chemical and thermo-chemical properties of biomass. It is, therefore, essential to know the composition of biomass from the point of view as fuel.
2.3.1 Biomass composition and types

The material of plants and animals, including their wastes and residues, is called biomass (Twidell and Weir, 2006). The initial energy of the biomass is captured from solar radiation in photosynthesis. The associated energy bound in photosynthesis is $2 \times 10^{12}$ J y$^{-1}$ out of which only 0.5% by weight is used as human food as crops. The carbon in biomass is obtained from CO$_2$ in the atmosphere via photosynthesis. When biomass is burnt or digested, the emitted CO$_2$ is recycled into the atmosphere, so not adding to atmospheric CO$_2$ concentration over the lifetime of the biomass growth. Energy from biomass is therefore 'carbon neutral'.

Biomass is usually composed of the elements carbon, hydrogen and oxygen. In addition, there may be nitrogen and sulphur. But, unlike in solid fossil fuel coal, these elements are present only in small quantities in biomass and, therefore, they may be neglected. Ash, with a few exceptions, is normally considered as a minor component in biomass. The three major elements of biomass carbon, oxygen and hydrogen are present with the approximate proportion of about 50%, 6% and 44% respectively on a moisture and ash free basis (Sharma, 1993). In general biomass can be represented by the empirical formula of CH$_{1.44}$O$_{0.66}$. Moreover the basic elements C, H, and N are present in the complex macroscopic polymeric forms: cellulose (C$_6$H$_{10}$O$_5$)$_x$, hemicelluloses (C$_5$H$_9$O$_4$)$_y$ and Lignin (C$_9$H$_{10}$O$_{9}$(CH$_3$O))$_{0.9-1.7}$. The composition of these constituents varies with the plant species. However, typically biomass is composed of 50% cellulose, 25% hemicelluloses and 25% lignin. The heat of combustion of biomass based fuels is dependent on the percentage of these three main constituents. Lignin has the highest 26.63 MJ/kg, while holocellulose (cellulose and hemicelluloses) has a value of 17.46 MJ/kg. Therefore, wood with a greater percentage of lignin has higher heat of combustion. The average calorific value of biomass may be considered as 16 MJ/kg.

The biomass fuels can be divided, quite generally, into four primary classes: 1) wood and woody materials, 2) herbaceous and other annual growth materials, such as straws, grasses, leaves, 3) agricultural by products and residues including shells, hulls, pits, and animal manures and 4) refuse-derived fuels RDF and waste or non-recyclable papers, often mixed with plastics. The later class is often excluded from the category of
biomass, but the origin, with the exception of mixed plastics, is appropriate for inclusion as a biomass type (Jenkins B.M. et al., 1998).

2.3.2 Biomass gasification process

Gasification is a very complex thermo-chemical conversion process, in which the biomass undergoes drying, pyrolysis, oxidation/combustion and reduction in a reactor in presence of a gasifying agent such as oxygen, air or steam etc. Gasification, in fact, is not an isolated phenomenon in a thermo-chemical conversion of biomass, because it is accompanied by pyrolysis and combustion and, therefore, difficult to explain. However, a flaming matchstick diagram (Fig. 2.2) may be helpful in understanding the processes involved in pyrolysis, reduction, and combustion. The flame (600-1500 °C) provides heat for pyrolysis. Pyrolysis occurs at temperature nearly 400 °C and jet of gaseous phase of pyrolytic products passes out through the hot char surface due to buoyancy effect and undergoes combustion in presence of sufficient air streams, which may be called ‘flaming combustion’. The solid phase of the pyrolytic product, char, also undergoes combustion producing CO₂ and water. The overall combustion reaction can be written as follows:

\[
\text{CH}_{1.4}\text{O}_{0.6} + \text{Air} (\text{O}_2) \text{ (sufficient)} \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\]

Fig.2.2 The flaming matchstick diagram showing the thermo-chemical conversion processes (Source: Reed and Das, 1998)
If the air passing through the mass of burning wood is insufficient, the products will be rich in CO and H₂ what is called 'flaming pyrolysis', the basis of biomass gasification. During flaming pyrolysis, limited air is allowed to pass through a burning biomass and the fuel-rich condition due to insufficient air would follow the following reaction:

\[ \text{CH}_{1.4}\text{O}_{0.6} + \text{Air (insufficient)} \rightarrow \text{CO}, \text{H}_2, \text{CH}_4, \text{C (Char)}, \text{CO}_2, \text{H}_2\text{O} \text{ and N}_2 \]

The relative fractions depend on the air-fuel ratio or more specifically equivalence ratio (\(\Phi\)), the ratio of actual quantity of air supplied to the stoichiometric air. For pure pyrolysis \(\Phi = 0\), for pure combustion \(\Phi = 1\) and for pure gasification \(\Phi = 0.25\) (Fig. 2.3).

In practice these reactions occur in a packed bed in a controlled environment called a reactor. Fresh biomass is dried and subsequently heated to an elevated temperature to undergo pyrolysis in a reactor, where air is supplied in limited quantity. The pyrolytic products burn to liberate heat energy. This heat of combustion is utilized for the remaining endothermic processes - reduction, pyrolysis and drying. The products of combustion and the hot char undergo reduction reaction and the products of this reduction reaction is fuel rich as it contains combustible gases CO, CH₄, and H₂, all burnable gases (refer to fig.2.4). On an average 1 kg of biomass, say for example wood, produces about 2.5 m³ of producer gas at STP. In this process, it consumes about 1.5 m³ of air which is about 33% of theoretical stoichiometric air (\(\varphi = 0.33\)) for wood (wood requires approximately 4.5 m³ of air for combustion). One of the measures of performance of a gasifier is conversion efficiency (about 60-70% for wood gasifier), which may be defined as the ratio of calorific value of the gas per kg of fuel to average calorific value of one kg of biomass. The average temperature of the gas leaving the gasifier is about 300-400 °C or even less for updraft gasifier. A high temperature of exit gas (~ 500 °C) is indicative of partial combustion of the gas, which may happen for higher air flow rate than the design value.
Fig. 2.3 Effect of equivalence ratio on thermo-chemical conversion of biomass (Reed and Ghandour, 2005) [P: Pyrolysis, G: Gasification, C: Combustion]

Fig. 2.4 Schematic representation of Biomass Gasification Process for production of Producer Gas

[DB: Dry biomass; CPP: Combustible pyrolytic products; PC: Products of combustion; H: Heat of Combustion]
2.3.3 Gasification process chemistry

From thermo-chemical reaction point of view, gasification is a two step process of combustion and reduction. However, four distinct processes take place in a gasifier as the fuel moves down towards the grate. Though there is a considerable overlap of the processes, each process may be assumed to occupy a separate zone in the reactor.

a) Drying

Drying involves removal of moisture content (10-30 wt %) from the wet biomass within 200 °C. During drying some organic acids also come out and these acids are corrosive in nature.

b) Pyrolysis

Pyrolysis is an intricate process, which is still not completely understood. The products depend on temperature, pressure, residence time and heat losses. However, a general explanation of the pyrolysis is given. At temperatures above 200 °C and up to 280 °C, carbon dioxide, acetic acid and water are given off. The real pyrolysis, which takes place between 280-500 °C, produces char, large quantities of volatiles, gases and tar.

c) Combustion

Combustion, occurring in the oxidation zone, is exothermic and yields a theoretical oxidation temperature of about 1450 °C. The main reactions are:

\[
\begin{align*}
\text{C} + \text{O}_2 &= \text{CO}_2 \quad (\Delta H = -401.9 \text{ kJ/mol}) \quad (1) \\
\text{H} + \frac{1}{2}\text{O}_2 &= \text{H}_2\text{O} \quad (\Delta H = -241.1 \text{ kJ/mol}) \quad (2)
\end{align*}
\]

Thus, burning of 1 mol of carbon to carbon dioxide releases a heat quantity of 401.9 kJ.

d) Reduction

The most important reactions that take place in the reduction zone of a gasifier between the different gaseous and solid reactants are (Rao, 2003):
\[ C + 2H_2 = CH_4 \quad (\Delta H = -91 \text{ kJ/mol}) \quad (3) \]
\[ C + H_2O = CO + H_2 \quad (\Delta H = 135 \text{ kJ/mol}) \quad (4) \]
\[ C + CO_2 = 2CO \quad (\Delta H = 169.8 \text{ kJ/mol}) \quad (5) \]
\[ CO + H_2O = CO_2 + H_2 \quad (\Delta H = -34.0 \text{ kJ/mol}) \quad (6) : (4-5) \]
\[ CO + 3H_2 = CH_4 + H_2O \quad (\Delta H = -226.6 \text{ kJ/mol}) \quad (7) : (3-4) \]

Equations (4) and (5) are the main reactions of the reduction stage and require heat. As a result, the temperature will decrease during the reduction. Equation (6) describes the so-called water-gas equilibrium. For each temperature, in theory, the ratio between the product of the concentration of carbon monoxide (CO) and water vapour (H\(_2\)O) and the product of the concentrations of carbon dioxide (CO\(_2\)) and hydrogen (H\(_2\)) is fixed by the value of the water gas equilibrium constant (\(K_w\)). \(K_w\) is given by the following formula:

\[
K_w = \frac{[(CO) \times (H_2O)]}{[(CO_2) \times (H_2)]}
\]

In practice, the equilibrium composition of the gas will only be reached in cases where the reaction rate and the time for reaction are sufficient. The reaction rate decreases with falling temperature. In the case of the water-gas equilibrium, the reaction rate becomes so low that the equilibrium is said to be 'frozen'. The gas composition then remains unchanged. Introduction of the water-gas equilibrium concept provides the opportunity to calculate the gas composition theoretically from a gasifier, which has reached equilibrium at a given temperature. The next table presents typical gas composition data as obtained from commercial wood and charcoal co-current gasifiers operated on low to medium moisture content fuels (wood 20%, charcoal 7%), [FAO 1986]
Table 2.1 Typical gas composition data from commercial co-current gasifier

<table>
<thead>
<tr>
<th>Component</th>
<th>Wood gas (Vol. %)</th>
<th>Charcoal gas (Vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>50-54</td>
<td>55-65</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>17-22</td>
<td>28-32</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>9-15</td>
<td>1-3</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>12-20</td>
<td>4-10</td>
</tr>
<tr>
<td>Methane</td>
<td>2-3</td>
<td>0-2</td>
</tr>
<tr>
<td>Heating value (MJ/Nm³)</td>
<td>5-5.9</td>
<td>4.5-5.6</td>
</tr>
</tbody>
</table>

Source: (FAO 1986);

2.4 Fixed-bed Biomass Gasifier Technology:

Biomass gasification allows the conversion of different biomass feedstock to a more convenient gaseous fuel that can be used in conventional equipment (e.g., boilers, engines, and turbines) or advanced equipment (e.g., fuel cells) for the generation of heat and electricity (Bauen, 2004). The conversion of Biomass, a low energy density solid fuel, to a gaseous fuel provides a wider choice of technologies for heat and electricity generation for small to large scale applications. The upgrading of biomass feedstock to gaseous fuels can also contribute to a cleaner conversion. Gasification processes convert biomass into combustible gases that ideally contain all the energy originally present in the biomass. In practice, gasification can convert 60% to 90% of the energy contained in the biomass into energy in the gas (Reed and Das, 1988).

A biomass gasification system primarily consists of a reactor into which solid fuel is fed and burnt using a limited (less than stoichiometric) supply of air. Heat for gasification is generated through partial combustion of the feed material. The resulting chemical breakdown of the fuel and internal reactions results in a combustible gas. The heating value of this gas varies between 4.0 and 6.0 MJ/Nm³ (Rajvanshi, 1986). Small-scale gasifiers are all of the "fixed-bed" bed type. The present study, therefore, confined to fixed bed gasifiers only. The fixed-bed reactors are often classified depending on the
relative directions of the solid flow and the gas stream (updraft, downdraft and crossdraft) [Fig. 2.5 (a-c)]

2.4.1 Updraft or counter current gasifier:

The simplest type of gasifier is the fixed bed counter current gasifier. The biomass is fed at the top of the reactor and moves downwards as a result of the conversion of the biomass and the removal of ashes. The air intake is at the bottom and the gas leaves at the top. The biomass moves in counter current to the gas flow and passes through the drying zone, the distillation zone, reduction zone and the oxidation zone. The major advantages of this type of gasifier are its simplicity, high charcoal burn-out and internal heat exchange leading to low gas exit temperatures and high gasification efficiency. In this way, fuels with high moisture content (up to 50 % wb) can also be used. Major drawbacks are the high amounts of tar and pyrolysis products, because the pyrolysis gas passes not through the low temperature drying zone preventing further cracking of the tar. However, this is of minor importance if the gas is used for direct heat applications, in which the tar is simply burnt. In case the gas is used
for engines, gas cleaning is required, resulting in problems of tar-containing condensates.

2.4.2 Downdraft or co-current gasifier

In a conventional downdraft gasifier, biomass is fed at the top of the reactor and air is introduced at the top or from the sides. The gas leaves at the bottom of the reactor, so the fuel and the gas move in the same direction (co-current). The pyrolysis gases are lead through the oxidation zone (with high temperatures) and burnt or cracked. Therefore, the major advantage of the gasifier is less amount of tar content in the producer gas, which is suitable for engine applications. There are certain drawbacks of downdraft gasifiers. Some of the drawbacks are: high amounts of ash and dust particles in the gas, sensitive to fuel properties, high temperature of outlet gas leading to low gasification efficiency, low moisture content biomass is acceptable, suitable for use in a power range of 80 kWe to 500 kWe. A recent development in downdraft gasifier is the 'open core' gasifier. These gasifiers are designed for gasification of small sized biomass with high ash content. In the open core gasifier, the air is sucked over the whole cross section from the top of the bed. This facilitates better air or oxygen distribution and thereby prevents local extremes (hot spots) in the solid bed, which is observed in the oxidation zone of conventional gasifiers due to poor heat transfer. Moreover, the air nozzles in conventional gasifiers generate caves and create obstacles that may obstruct solid flow, especially, for solids of low bulk density like rice husk.

2.4.3 Crossdraft gasifier:

In crossdraft gasifiers, the solid fuels move in a direction perpendicular to the direction of gas flow. The temperature of the gas for solid biomass is found about 800-900 °C. Crossdraft gasifiers suffer from minimum tar cracking performance. Therefore, these gasifiers are adapted for the use of charcoal gasification. However, charcoal gasification results in very high temperatures (> 1500 °C) in the oxidation zone, which can lead to material problems. Advantages of the system lie in the very small scale at which it can be operated. In developing countries, installations for shaft power less than 10 kW are used. Because of the limited capacity of crossdraft gasifiers and the limited scope for large scale of implementation, the crossdraft gasifier types are not widely used.
2.4.4 Inverted downdraft or Top-lit updraft (T-LUD) gasifiers:

This type of gasifier is relatively new in concept and its applications are till now restricted to very small power level thermal applications, mostly in gasifier stoves. Of course, Saravanakumar et al. (2007b) in an experimental gasifier reports the use of T-LUD method for gasification of long stick wood. As the name indicates, this gasifier possesses some common characteristics of both updraft and down draft gasifiers. But simplicity in operation and capacity to produce relatively clean gas makes it a suitable candidate for small thermal applications. The basic principle of operation of the gasifier is similar to down-draft operation. But in the T-LUD gasifier shown in fig.2.6, the primary air is introduced at the bottom and the reaction zone is at the top. The top lit updraft is "tar burning, char making" gasifier. Tar is much lower (1% to 5% only depending upon the superficial velocity) due to the flaming pyrolysis of the biomass and the gases then pass through a layer of hot charcoal on the top, where the tars are further cracked. The gases also react with the char at the top of the bed and the char is reduced. Gas is produced at constant rate as the reaction zone descends or the flame front propagates downwards leaving behind a hot char bed. Because the reaction moves counter current to the air, the fuel bed is burned at the same rate as the reaction moves against the fuel.

Fig.2.6 Packed bed gasification in inverted down-draft or top lit up-draft operation
2.4.5 Power gasifier and heat gasifiers:

From application point of view, gasifiers are further classified as power gasifiers and heat gasifiers. Power gasifiers require a more or less tar-and-dust-free gas, while heat gasifiers are not very sensitive to these types of impurities. Generally, power gasifiers supply clean gas to a prime mover (e.g. I.C. Engine, Gas turbine) to produce work and electricity. The tar cleaning process in power gasifiers is expensive, and therefore, not economical for small scale applications. Heat gasifiers also need cleaning of the gas in some type of applications, but not to that extent of a power gasifier. The present study considers only heat gasifiers.

The advantage of heat gasifiers as compared to direct combustion of biomass is in obtaining controlled heating and higher flame temperature than those obtainable otherwise. These gasifiers are less demanding on cooling and cleaning equipment and have more versatility as far as fuels are concerned. However, for lower heat value (~ 5 MJ/m³) of the gas, it requires special design of burning equipment. The adiabatic flame temperature of producer gas is about 1400 °C and therefore, highest temperature applications can be around 1000-1200 °C.

2.5 Gasifier fuel (biomass) characteristics:

Each type of biomass has its own specific properties, which determine its performance as a fuel in gasification plants. The most important properties relating to gasification are:

- moisture content
- ash content
- elemental composition
- bulk density and morphology
- volatile matter content
- calorific value
2.5.1 Moisture content:

The moisture content of biomass is defined as the quantity of water in the material expressed as a percentage of the material's weight. For thermal conversion processes like gasification, preference is given to relatively dry biomass feedstock, because a higher quality gas is produced, i.e., higher heating value, higher efficiency and lower tar levels.

2.5.2 Ash content and ash composition:

Ash is the inorganic or mineral content of the biomass, which remains after complete combustion of the feedstock. The amount of ash differs widely in different types of feedstock, from 0.1% in wood to 15% in some agricultural products, and influences the design of the reactor, particularly the ash removal system. The chemical composition of the ash is also important, because it affects the melting behaviour of the ash. Ash melting can cause slagging and channel formation in the reactor. Slag can ultimately block the entire reactor.

2.5.3 Elemental composition:

The elemental composition of the fuel is important with regard to the heating value of the gas and to the emission levels. The production of nitrogen and sulphur compounds is generally small in biomass gasification because of the low nitrogen and sulphur content in biomass.

2.5.4 Bulk density and heating value:

Bulk density refers to the weight of material per unit of volume and differs widely between different types of biomass. Together with the heating value, it determines the energy density of the gasifier feedstock, i.e., the potential energy available per unit volume of the feedstock. Biomass of low bulk density is expensive to handle, transport and store. Apart from handling and storing behaviour, the bulk density is important for the performance of the biomass as a fuel inside the reactor. With low density, a high voidage tends to result in channelling, bridging, incomplete conversion and a decrease in the capacity of the gasifier. The bulk density varies widely (100 -
1000 kg/m$^3$) between different biomass feedstock. The higher the energy content and bulk density of fuel, the smaller is the gasifier volume.

2.5.5 Volatile matter content:

The amount of volatiles has a major impact on the tar production levels in gasifiers. Depending on the gasifier design, the volatiles leave the reactor at low temperatures (Updraft gasifiers) or pass through a hot incandescent oxidation zone (downdraft Gasifiers), where they are thermally cracked. For biomass materials the volatile matter content varies between 50 and 80%.

2.6 Tar formation in gasifiers:

One of the major problems of biomass gasification process is formation of tar. Tar is a complex mixture of condensable hydrocarbons (some experts define tar as all organic contaminants with a molecular weight larger than benzene) generated in the gasification process of cellulosic biomass. Tar in producer gas is a serious problem when the gas is used to run thermal prime movers such as in power generation. Tar also lowers the calorific value of the produced gas. Tar control technologies can broadly be divided into: 1) primary methods i.e. treatment inside the gasifier and 2) secondary methods i.e. hot gas cleaning after the gasifier. Although secondary methods are proven to be effective, treatments inside the gasifier is economically more beneficial. In primary methods, the operating parameters such as temperature, gasifying agent, equivalence ratio, residence time and catalytic additives play important roles in the formation and decomposition of tar. Moreover, reactor design and factors such as fuel moisture content, volatile content etc. play vital role.

However, the minimum allowable limit for tar is highly dependent on the kind of process and the enduse applications. It may be added here that tar is not a serious problem in small thermal gasifiers where the gas is burnt immediately after production such as in a close coupled gasifier combustor used in modern gasifier based stoves. In case of combustion of the gas in external burners for thermal applications simple dry filters may be used to clean the gas before combustion. Low power thermal gasifiers, therefore, have the inherent advantage of minimum attention in tar formation.
2.7 Feedstock preparation requirements:

Feedstock preparation is required for biomass materials, because of large variation in physical, chemical and morphological characteristics. The degree, to which the pre-treatment is desirable, depends on the gasifier plant. Sizing and drying are the most essential pre-treatment of biomass feedstock.

Sizing:

Sizing of the feedstock may be necessary as different sizes are specified for different types of gasifiers. For small scale fixed bed gasifiers small biomass chips such as sized wood blocks are preferred. Biomass such as saw mill waste chips could be directly used in large scale gasifiers by proper screening or shivering.

Drying:

Drying is necessary for fresh biomass to remove extrinsic moisture. For small scale applications, open air drying or solar drying may be preferred. Natural drying in open air is cheap but time consuming. Artificial drying is expensive, but is more effective in large scale use. Waste heat from engines etc. can be used economically for artificial drying. Rotary kilns are also used as dryers.

2.7 Summary:

The energy recovery from biomass through gasification has gained renewed interest. The main constituents of biomass cellulose, hemicelluloses and lignin vary for different biomass. The average calorific value of biomass is about 16 MJ/kg. Biomass gasifiers are both fixed and fluidised bed type. Fixed bed gasifiers are particularly suitable for small-scale application. Updraft, downdraft and crossdraft are the three main classification of fixed bed gasifier with their relative merits and demerits. For very small applications, a relatively new gasifier is used, which is called inverted down draft or top lit updraft gasifier. Gasifier design and fuel properties are both important for successful gas generation. A vital parameter in gasifier operation is the equivalent ratio. The main challenge before gasifier development is tar reduction with consistency in operation. However, for direct heat gasifiers, the presence of tar is not considered as a major drawback as it could be simply burnt to add heat to the heat of gas combustion.