A Study of Bio Mass Gasifier Performance Evaluation: An Analysis

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Abstract

The process of converting biomass into practical, vaporous energies or complex feedstock is known as biomass gasification. It has become a potentially useful tool to address the Increasing global energy consumption as well as reducing the amount of biomass waste produced in underdeveloped countries societies. The paper discusses a variety of research and development of downdraft fixed bed biomass gasification improvements in downdraft gasification systems, as well as the impact different characteristics, including equivalence, moisture content, operational temperature, and superficial on the effects of speed, gasifying agents, and residence duration on the composition of review of producer gas, yield, and conversion Gasification is a productive method for producing valuable goods from biomass with a variety of possible uses, which has gotten more and more consideration throughout the years. Further for gasification technology to advance, creative and technologies for gasification that are efficient and affordable. Various both traditional methods of biomass gasification and novel technologies are addressed. In actuality, the rising the need for renewable energy is prompted by climate change. Owing to the GHG emissions brought on by the extensive usage of compared to traditional fossil fuels, biomass gasification is thought to as a possible ecologically responsible and sustainable technology. However, social and environmental considerations should also be considered while creating such facilities, to ensuring biomass is used sustainably. This paper also examines the research on biomass life cycle assessment (LCA) gasification, taking numerous technologies and approaches into feedstocks.

Keywords: bio mass; gasification; process intensification; process combination; polygeneration;

Introduction:

Gasification is the conversion of dense or liquid carbonaceous feedstocks into a vaporous fuel (combination gas, maker gas), mostly carbon monoxide, ethane, and other lighter vaporised hydrocarbons that may be related to carbon dioxide and nitrogen depending on the procedure used. From robust feedstocks, gasification procedures also provide fluids (tars, oils, and other condensates) and solids (roast, debris). The primary goal of gasification procedures is to produce fuel or mixtures of gases. Power tools, other major actors, and inner and outer ignition motors may all make use of fuel gases. Methanol, Fischer-Tropsch (FT) fluids, as well as other fuel fluids and synthetic compounds, may all be produced using gasification products. Similar classes of products are produced by instantaneous burning of solids and by gasification of solids, however with gasification, pollution control and transformation efficiency may be increased. The peculiarities of environmental change or the rise in global temperatures brought on by the emissions of CO_2, NOx, and SOx pose a major threat to people and other animals.

According to the global energy viewpoint (www.eia.gov), worldwide CO_2 emissions connected to energy will rise from 30.2 billion metric tonnes in 2008 to 43.2 billion metric tonnes in 2035. It is essential to switch from conventional to limitless power sources, such as biomass, solar, wind, and hydroelectric energy, since ozone-harming substance (GHG) emissions from duplicating petroleum products for power age are a big backer of environmental change (Sikarwar et al., 2016). Biomass has an advantage over other endless sources since it is distributed more fairly around the planet and is also easily available (Akia et al., 2014; Clamor and Zainal, 2016; Gottumukkala et al., 2016). In fact, biomass now provides over 10% of the world's energy, ranking fourth in importance after coal, gasoline, and flammable gas (Saidur et al., 2011). By 2050, it is predicted that biomass and garbage would provide between a quarter and a third of the world's primary energy sources (Bauen et al., 2009). In 1792, gasification's primary acknowledged use in the production of electricity was recorded. However, the fluidized bed gasifier (FBG), which was essentially invented in 1926 and led to the construction of the first commercial coal gasification plant at Wabash Waterway in the USA in 1999, was developed by Siemens in 1861.

Biomass gasification has gradually gained popularity since roughly 2001 as a consequence of high oil prices and concerns about environmental change (Basu, 2010). A thermochemical incomplete oxidation process called biomass gasification converts biomass into gas under the supervision of gasification experts, using air, steam, oxygen, carbon dioxide, or a mixture of these (Ruiz et al., 2013). Along with light hydrocarbons like ethane and propane, as well as heavy hydrocarbons like tars, the syngas product is a mixture of CO, H2, CH4, and CO2. The feedstock material, gasifying expert, reactor design, the existence of impetus, as well as the functioning states of the reactor, all have an influence on the kind of released gas (Parthasarathy and Narayanan, 2014).

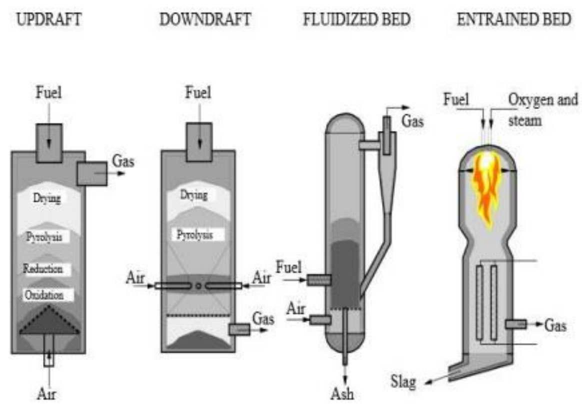
The syngas' lower warming value (LHV) varies from 4 to 13 MJ/Nm3 depending on the feedstock, gasification technology, and operational conditions (Basu, 2013). The produced burn consists of both unconverted natural material and detritus (as an element of the treated biomass). The single's LHV ranges from 25 to 30 MJ/kg depending on the amount of unconverted natural division (Molino et al., 2016).

Syngas may be processed into methanol, dimethyl ether, Fischer Tropsch (F-T) syncrude, and other synthetic chemicals, while biomass can be utilised to replace non-renewable energy sources in the production of syngas, hydrogen, electricity, and intensity (Leibbrandt et al., 2013; Petersen et al., 2015). A few possible benefits of biomass gasification include supportability, territorial economic growth, social and rural improvements, and a reduction in GHG emissions (Demirbas and Demirbas, 2007).

The gasification cycle genuinely anticipates development to increase the interaction's energy effectiveness by overcoming basic challenges like tar production and the moisture content of the biomass. There are now more effective techniques to use even toxic and moist biomass for energy generation.

Technologies for Gasification

Biomass is subjected to a mixture of drying, pyrolysis, combustion, and other processes throughout the gasification process. reactions that gasify. Gasification of biomass has been created as a means of waste valorization to produce goods such as chemical feedstocks, H2, CH4, and syngas. The fixed bed is one of the standard gasification processes. Fluidized bed, entrained flow, and (updraft and downdraft) reactors, which are shown in Figure 1. a larger selection of new More advanced gasification methods have been developed, incorporating supercritical gasification and plasma gasification Water from wet biomass is used to create gas from a variety of feedstocks. in 2015; Sikarwar et al., 2015; Heidenreich and Foscolo, 2015 ,2016). Additionally, process combinations and integrations work toincrease process effectiveness, improve gas quality, and purity with less expensive investments. Consequently, the alleged There has been an increase in interest in "emerging technology." current examples include combining gasification with gas cleansing technologies, such as gasification and pyrolysis in combination, combustion. a list of innovative technology applications biomass combustion.



Types of Biomass

Biomass may be categorized into two main categories:

- Virgin Biomass,
- Waste

Directly from plants or animals are where primary or virgin biomass originates. Different biomass-derived products yield waste or derived biomass. A variety of biomass kinds are included in Table I, which groups them as virgin or trash. In short-rotation or energy plantations, energy crops, a virgin biomass, are cultivated specifically for the purpose of generating energy. They include herbaceous energy crops, woody energy crops, industrial crops, agricultural crops, and aquatic crops. Eucalyptus, willows, poplars, as sorghum, sugar cane, soy beans, sunflowers, cotton, etc. are typical examples. These plants may be used to produce biofuels, synthesis gas, and hydrogen via combustion, pyrolysis, and gasification. Agricultural plant residues are generated in significant amounts.

Components of Biomass

It is discovered that cellulose, hemicellulose, lignin, and extractives are the main constituents of biomass. According to these components, the composition of biomass has been published by Raveendran et al.

reproduces same outcomes with other biomasses.

While herbaceous plants are typically perennial and have more loosely bound fibers, indicating a lower proportion of the lignin that binds the cellulosic fibers together, woody plant species are typically characterized by slow growth and are composed of tightly bound fibers, giving a hard external surface. The relative amounts of cellulose and lignin are two characteristics that help determine which plant species are suitable for processing into energy crops later on.

Composition of Biomass

Carbon, hydrogen, and oxygen are the three main chemical constituents of biomass. The final analysis enables the measurement of these element fractions. The CxHyOz formula, in which x, y, and z indicate the corresponding elemental fractions of C, H, and O, is used to report final results.

It is typical to present the proximate analysis in order to completely characterise biomass properties. The composition of the biomass is determined by proximate analysis in terms of its gross components, including moisture (M), volatile matter (VM), ash (ASH), and fixed carbon (FC). It is a rather easy and cheap operation. Various biomass feed supplies' ultimate and proximate analyses are shown in Tables III and IV, respectively. In comparison to proximal analysis, ultimate analysis is more complex and costly.

Chemistry of Gasification

The carbonaceous material passes through a number of various processes in a gasifier, including drying, pyrolysis, combustion, and gasification. At around 100°C, the dehydration or drying process starts. If the temperature is high enough, the resultant steam, which is often mixed with the gas flow, may participate in subsequent chemical processes, most notably the water-gas reaction. Pyrolysis (or devolatilization) takes place between 200 and 300 °C.

Up to 70% of the weight of the biomass is lost as a consequence of volatiles being released and char being created. The procedure defines the structure and content of the char, which will subsequently go through gasification processes, and is reliant on the characteristics of the carbonaceous material. The combustion phase takes place when the char and certain volatile products combine with oxygen to predominantly generate carbon dioxide and trace quantities of carbon monoxide, which serves as heat for the following gasification processes. Here, the default response is

$$C + O_2 \leftrightarrow CO_2 \quad (1)$$

$$\Delta H = -393.5 \text{ kJ/mol}$$

Char combines with carbon and steam to form carbon monoxide and hydrogen during the gasification process.

$$C + H_2O \leftrightarrow H_2 + CO \quad (2)$$

$$\Delta H = 131.3 \text{ kJ/mol}$$

In addition, the reversible gas phase water gas shift reaction reaches equilibrium very fast at the temperatures in a gasifier. These balances the concentrations of carbon monoxide, steam, carbon dioxide and hydrogen.

$$CO + H2O \leftrightarrow CO2 + H2 \ (3)$$

$$\Delta H = -\ 41.1\ kJ/mol$$

In essence, a little quantity of oxygen or air is injected into the reactor to enable part of the organic material to burn, creating carbon monoxide and energy. This second reaction then transforms more organic material into hydrogen and more carbon dioxide. When the newly synthesised carbon monoxide and the remaining water from the organic material react, methane and surplus carbon dioxide are produced. In reactors that enhance the residence time of the reactive gases and organic components, as well as heat and pressure, this third reaction happens more often. The ternary is a tool for illustrating the conversion stages for biomass. The triangle's three sides stand for 100 percent pure forms of carbon, oxygen, and hydrogen.

The triangle's points indicate ternary combinations of these three chemicals. A pure component (C, O, or H) has zero concentration on the side that is opposite the corner where it is present. For instance, the horizontal base in the figure across from the hydrogen corner shows binary combinations of C and O that have zero hydrogen. Compared to coal, a biomass fuel is located nearer the hydrogen and oxygen corners. This implies that compared to coal, biomass has more oxygen and hydrogen. Lignin typically has more carbon and less oxygen than cellulose or hemicellulose. The figure may also show how fossil fuels have changed over time.

As fuel ages, it tends toward the carbon corner and away from the corners of hydrogen and oxygen.

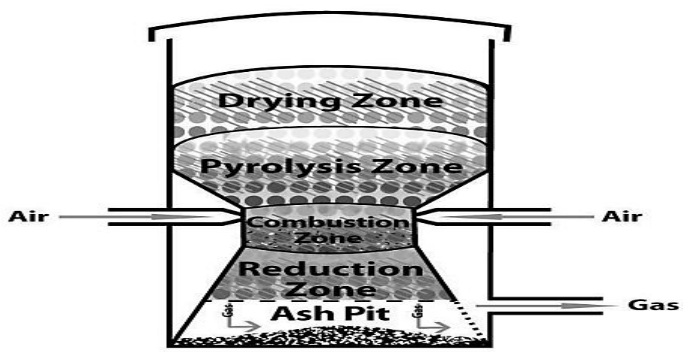


Diagram showing the different zones in the process of gasification in downdraft gasifier.

Design of Downdraft Gasifiers

The fixed bed gasification systems include downdraft gasifiers. Researchers from all around the globe are becoming more interested in downdraft gasification technology as a result of the potential for producing mechanical and electrical power from biomass on a modest scale and at a reasonable cost. The two primary types of downdraft gasifiers are the Imber gasifier (also known as a throated or closed top gasifier) and the stratified gasifier (also known as an open core or throatless gasifier). Bark, wood blocks, chip and pellets, straw, maize cobs, refuse derived fuel (RDF), and waste pellets have all been gasified using these gasifiers with different gasifying media such air, oxygen, and steam.

Gasifier types

The density factor, or ratio of solid stuff (the dense phase) a gasifier can burn to the total volume accessible, may be used to classify gasifiers.

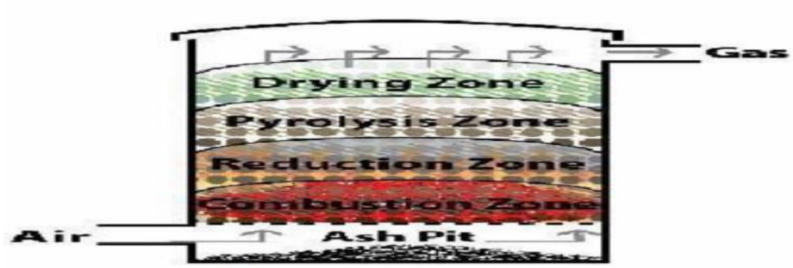
- Lean phase reactors
- Dense phase reactors may both be used as gasifiers.

Diffuse phase reactors

In dense phase reactors, the feedstock takes up the majority of the interior area. They come in three main varieties: downdraft, updraft, and cross-draft, are widely used, and have a variety of designs according on the working circumstances.

Co-current or downdraft gasifiers

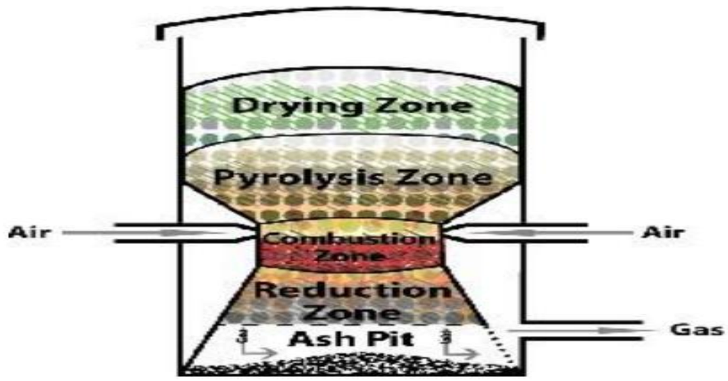
The most typical kind of gasifier is the downdraft (sometimes called co-current) gasifier. The pyrolysis zone and reduction zone are located above and below the combustion zone, respectively, in downdraft gasifiers. Fuel is supplied from above. Through the combustion and reduction zones, air and gas flow downward, hence the name. Because air goes downhill, in the same direction as fuel, this movement is referred to as co-current. Tar generated in the pyrolysis zone of a downdraft gasifier passes through the combustion zone and is either burned or broken down there. The outcome is a rather pure gas combination in the exit stream. The downdraft gasifier's key benefit is that it generates gas with a low tar content, making it ideal for gas engines, hence the location of the combustion zone is crucial.



Down draft gasifier

Counter-Current or Updraft Gasifier

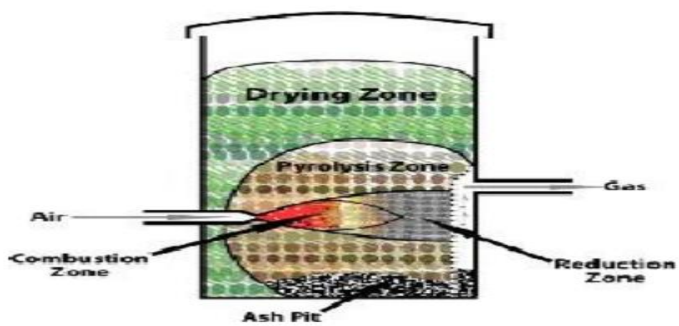
Air enters from below the grate and flows upward in updraft gasifiers (also known as counter-current), while fuel flows downhill. Zones specifically designated for partial combustion, reduction, pyrolysis, and drying exist inside an updraft gasifier. Along with the pyrolysis byproducts from the pyrolysis zone and the steam from the drying zone, the gas generated in the reduction zone exits the gasifier reactor.



Updraft gasifier

Cross-Draft Gasifier

Air enters a cross-draft gasifier from one side and exits the gasifier reactor from the other. Cross-draft gasifiers offer a few distinguishing benefits, including their small size and little maintenance needs. Additionally, cross-draft gasifiers do not need a grate since the ash settles at the bottom and does not obstruct regular operation.



Cross-draft Gasifier

Gas for Production Applications

Both heat and electricity may be produced using the producer gas that is acquired applications for heat.

Thermal Applications

Similar to liquid petroleum gas (LPG), producer gas may also be burned directly in the open air, making it useful for cooking, boiling water, creating steam, and drying food and other items.

- Kilns are used to fire materials including tiles, pottery, limestone, and refractories at temperatures between 800-950 °C.
- Boilers: In order to create steam or hot water, boilers may utilise producer gas as fuel.

Power Application

Producer gas may be used to provide motive power for engines that operate solely on producer gas (100% diesel replacement) or dual-fuel engines (which run on a combination of gas and diesel, with gas replacing up to 85% of diesel). In general, gasification has a substantially greater fuel-to-electricity efficiency than direct combustion:

While combustion only achieves a conversion efficiency of 10%–20%, gasification achieves a rate of 35%–45%. In addition to being utilised for chilling or cold storage, agricultural operations, irrigation, and other commercial and industrial purposes, generated power may also be sent into the grid.

Biomass from Wood:

Depending on the design, pieces must be no larger than 5-10 cm (2-4 inches) in any dimension. Bulk density of wood or briquettes must be less than 250-300 kg/m3.

Loose Biomass:

- Depending on the design, there may be pulverised biomass.
- moisture levels of up to 15% to 25%.
- Ash content less than 5%, with a maximum of 20%, is preferable.
- Loose biomass has a bulk density of less than 150 kg/m3.

Conclusion

The potential for biomass to help with the world's energy requirements is quite significant. The most practicable method for producing low calorific value gas for use in thermal applications or small-scale power generating plans is the fixed bed gasifier. The choice of gasification system is determined by the physical and chemical properties of the biomass, the gasifier's capacity, and the planned use of the system. The downdraft gasifier may be used in engine and thermal applications. Many nations now have fixed bed gasification system commercial installations. While various demonstration projects are now being implemented and gasification technologies have recently been successfully tested at a small scale by researchers, they still encounter economic and other non-technical challenges when attempting to compete in the energy markets. This may be accomplished via the combination of biomass systems with economic growth.

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