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Downdraft Gasifier: A Review

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Abstract: *Gasification is a thermo-chemical process which converts solid biomass into a mixture of combustible gases that can be used in several applications. A downdraft gasifier was designed and developed for running air cooled, single cylinder, 4-stroke, direct injection diesel engine developing a power of 5 kW, on dual fuel mode at a rated speed of 1500 rpm. The producer gas was introduced in the inlet manifold of engine at 81pm, 61pm and 41pm respectively. The emission and performance characteristics of the engine were studied for various gas flow rates at different loads condition. On the behalf of moisture calculation ,mass flow analysis ,energy flow analysis and elemental balance can improved the efficiency of downdraft gasifier.*
Key words: *Biomass, Gasifier, Performance, Producer gas, Efficiency*.

I. Introduction

Biomass is the oldest source of energy and currently biomass accounts for approximately 10% of total primary energy consumption. Most of the developing countries has growing their interest in biofuel development and providing greater access to clean liquid fuels while helping to address the issues such as increase in global warming and fuel price concerns associated with petroleum fuels. But most is the energy security. Abundant biomass is available throughout the world which can be converted into convenient energy. Dense biomass include, plant waste, animal waste, municipal waste, forest waste food waste, vegetable seeds and crops residues. Biomass is traditionally available in solid form Biomass is well-thought-out as a better source of energy because it bargains energy security, reduced GHG emission and rural employability. This Biomass can be converted into heat and power by adopting appropriate method. Fig. 1 shows the utilization of biomass to get various different outputs [1].

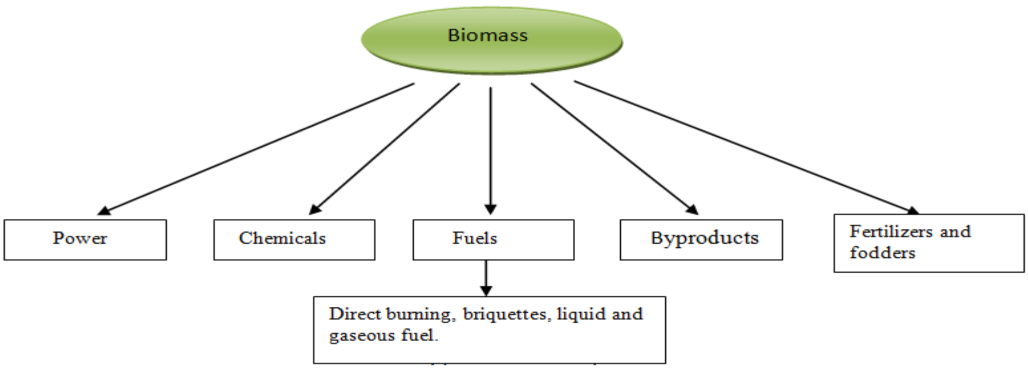

Fig.1. Utilization of biomass resources [1].

Thermo chemical conversion of woody biomass in restricted supply of oxidant is among the most capable non-nuclear forms of future energy. Furthermore utilizing a renewable energy sources, the technology also offers an self-sustainable and eco-efficient way of obtaining gaseous fuel generally called producer gas and it can also be used as either premixed burners (dryers, kilns, boilers or furnaces) for thermal applications or in direct feeding of high efficiency internal combustion engines/gas turbines for mechanical applications [2].

1.1 Benefits of biomass power

- Distributed generation
- Suited for rural areas
- Ability to have small, kW scale power production
- Rural economic upliftment
- Carbon neutral
- Efficient utilization of renewable biological sources
- Reduces methane, a major GHG gas
- Low Cost Resource

1.2 Principle Of Gasifier

Gasifier is relatively simple device and the mechanics of their operation, such as gas cleanup and feeding, also are uncertain and the prosperous operation of gasifier, however, is not so modest. On no account rules exist because the thermodynamics of gasifier operation are not well understood. Up till now, nontrivial thermodynamic principles dictate the air supply, temperature and other operating variables of the reactors that we build and it is a tribute to the persistence of experimentalists that so much progress has been made in the face of so little under standing. However, it has been the experience in related fields (such as oil, coal combustion and gas) that once the mechanisms at work are understood and it is able to develop cleaner, more efficient processes. Providentially, much of the knowledge acquired in these fields can be applied to enhance our understanding of gasification processes **[**3**].**

1.3 Classification Of Biomass Gasifier

Gasifier is classified as per the type of bed i.e. (1) fixed bed and (2) fluidized bed.

1.3.1. Fixed bed gasifier

1.3.1.1 Up Draft Gasifier

The geometry of the updraft gasifier is shown in Fig. 2. Biomass is fed into the top while air enters below the combustion zone through grate and flows upward through bed and the grate is mounted at the base of gasifier, steam and air reacts there with charcoal from biomass to produce very hot CO_2 and H_2O and this CO_2 and H_2O react endothermically with char to form CO and H_2. The producer gas has no ash but contains tar and water vapor because of passing of gas through unburnt biomass but, usually 5% to 20% of tars and oils are produced at temperature too low for significant cracking and are carried out in the gas stream and the remaining heat dries the wet biomass so that none of the energy is lost as sensible heat in the gas and the advantage of updraft gasifier over other gasifier is its high conversion efficiency up to 80% but it produces tar with producer gas which is the major feedback of updraft gasifier and its tar content producer gas cannot be used in engine application, it may corrode the engine parts like valve, piston and fuel line [4].

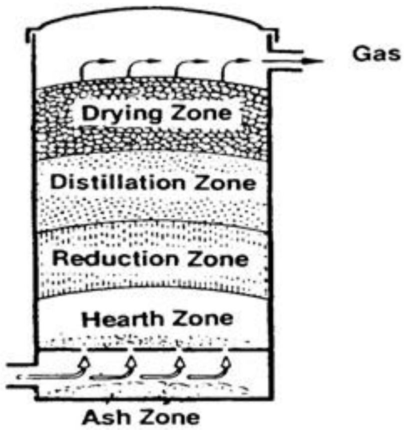

Fig.2. Updraft gasifier [4]

1.3.1.2 Downdraft Gasifier

In the downdraft gasifier, its upper cylindrical part of gasifier acts as a collection device for wood chips or other biomass fuel and the geometry of the downdraft gasifieris shown in Fig. 3. Below this cylindrical part of gasifier, nearby is a radially directed air nozzle which permits air to be drawn in to chips as they move down to be gasified and this nozzle constitutes combustion and reduction zone as shown in Fig. 3. After the air contacts the pyrolyzing biomass before it contacts with char and support a flame and the limited air supply in the gasifier is rapidly consumed, therefore that the flame gets richer as pyrolysis proceeds. Next to the end of pyrolysis zone, the gases consist mostly of CO_2, H_2O, CO and H_2 and the throat ensures that the gaseous products pass through the hottest zone someplace most of the tar cracked into gaseous hydrocarbon. So produces relatively clean gas. Designed for the application of producer gas in CI engine, downdraft gasifier is more suitable as it produces very less tar[4].

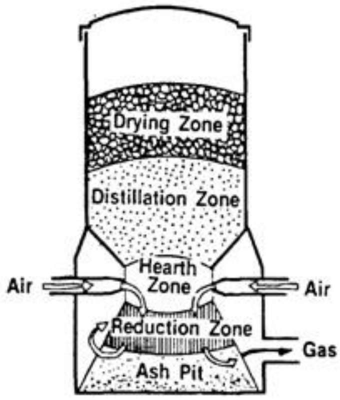

Fig.3. Downdraft gasifier [4]

1.3.1.3 Crossdraftgasifier

The crossdraftgasifier is shown in Fig. 4 and air enters at high velocity through a water cooled nozzle mounted on one side of the induces substantial circulation, firebox, and flows across the bed of char and fuel. The gas is produced in the horizontal direction in front of the nozzle and passes through a vertical grate into the hot gas port on the opposite side and this produces very high temperature in a very small volume and results the production of very low tar gas. However, the cross draft gasifier is not commonly used [5].

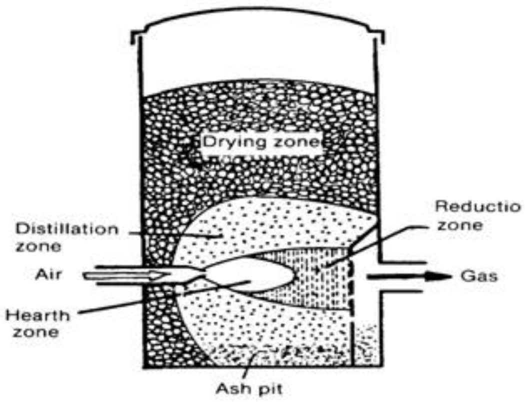

Fig.4. Cross-draft gasifier [5]

1.3.2 Fluidized Bed Gasifier

Fluidized bed gasification system is used for the fuel which the ash has low melting point and has high ash contents and in fluidized bed gasifier the air is blown upwards through the biomass bed and the bed under such conditions behaves like boiling fluid and has excellent temperature uniformity and provides efficient contact between solid phase and gaseous and generally the heat is transferred initially by hot bed of sand and normally the operation temperature of the bed is maintained within the range of 750-950^{0}C, therefore that the ash zones do not get heated to its initial deformation temperature and this prevents clinkering and slagging and the major advantage of fluidized bed gasifier over downdraft is its flexibility with regard to feed rate and rate of consumption but it produces more tars and ash as compared to downdraft gasifier . This puts a heavy load on cooling train and cleaning [6].

1.4 Advantages Of Downdraft Over Updraft

- Gas with less tar.
- More suitable with some thermal applications.
- Fuel specific.
- Minimum bulk density of 250kg/m3.
- Ash content of less than 5%.
- Gas comes out of the gasifier at 250-450 Celsius.

II. Literature Survey

Gasification was discovered independently in both England and France in 1798, and through 1850 technology had been developed to the point that it was possible to light much of London with manufactured gas or "town gas" from coal and manufactured gas soon crossed the Atlantic to the United States and, through 1920, most American cities and towns supplied gas to the residents for lighting and cooking through the local "gasworks."

In 1930, the first natural gas pipeline stood built to transport natural gas to Denver of Texas from the oil fields. As pipelines intersected the country, low cost natural gas displaced manufactured gas and the once-widespread industry soon was overlooked. "Town gas" continued to be used in England until the 1970s, but then again the plants were dismantled following the discovery of North Sea oil. At the moment, a few plants are still operating in the third world [7].

Gasification was rediscovered in an area of higher oil prices and fuel shortages and there are gasifier engine projects under way in more than 20 countries for producing process heat and electrical and mechanical power. In its rebirth, conversely, the existing technology has uncovered major problems in connection with effluent and gas cleanup and the fuel supply, which were less important during the emergency of World War II. In the present day, these problems must be solved if biomass gasification is to reemerge a fuel source. Superficially, it is going to take a few years for the technology of the 1980s to be effectively applied to the accomplishments of the 1940s. Automated advances in materials and control systems are available for use in today's process designs, so a continuous development effort and lively open exchange should enable us to incorporate latter-day chemical and chemical engineering techniques to convenient, build clean and reliable systems[8].

The thermochemical reaction in gasification may be different with varying parameters and the size of biomass and for a particle size below 1mm diameter, thermochemical reaction shows a sharp increase in the fuel conversion which could be used in conventional entrained flow gasifier and the reduction in the fuel particle size led to an improvement in the gas quality and thus to a higher producer gas heating value and maximum fuel conversion was obtained for the smallest particle size tested and the thermochemical characterization of the char-ash residue showed that as the fuels particle size was reduced and the release of volatile matter during pyrolysis stage along with particle carbonization and it gradually increased which is suggest that pyrolysis reaction took place to a great extent. Meant for fuel particle size of 2mm and the reaction of char gasification became more relevant which contribute in the improvement of conversion of fuel and the composition of producer gas [9].

2.1 Challenges

The price of biomass is dependent on various factors like availability, transportation, and drying, etc. Feed stock homogeneity, consistency and reliability are questionable. Storage and handling is difficult (particularly stability in long term storage). Flash point in blends is unreliable. Compatibility with I.C. engine material needs to be studied further. Acceptance by engine manufacturers is another major difficulty. Continuous availability of the particular type of biomass needs to be assured before embarking on the major use of it in I.C. engines [10].

2.2 Technical difficulties

Development of less expensive quality tests, emission testing with a wide range of biomass feed stocks. Studies on developing specific markets such as mining, municipal water supplies, etc. which can specify bio-diesel as the fuel choice for environmentally sensitive areas. Co-product utilization like ash produced in a beneficial manner. Efforts are focused on responding to fuel system performance, material compatibility and low fuel stability under long term storage. Continued engine performance, emissions and durability testing in a variety of engine types and sizes need to be developed to increase consumer and manufacturer confidence. Environmental benefits offered by biomass over diesel fuel needs to be popularized. Studies are needed to reduce cost and identify potential markets in order to balance cost and availability [10].

III. Performance Prediction & Efficiency Improvement Of Downdraft Gasifier.

3.1 Gasification

Gasification is a thermo-chemical process by which carbonaceous (hydrocarbon) materials (coal, biomass, petroleum, coke etc.) can be converted to a synthesis gas (syngas) or producer gas by means of partial oxidation with air, oxygen, or steam and the device which performs this work is known as gasifier. And the gasifier is a chemical reactor where various complex chemical and physical processes take place and a hydrocarbon feedstock (biomass) is fed into a high-pressure, high temperature chemical reactor (gasifier) containing steam and a limited amount of oxygen. Such as biomass flows through the reactor it gets dried, pyrolysis, heated partially oxidized and reduced. In these “reducing” conditions and the chemical bonds in the feedstock are severed by the extreme heat and producer gas and pressure is formed and the main constituents of producer gas are hydrogen (H_2) and carbon monoxide (CO). In a word, the task of gasifier is to pyrolysis the biomass to produce volatile matter, gas and carbon and to convert the volatile matter into permanent gases, CH_4 ,CO and H_2[11].

Composition of producer gas:-
- Carbon monoxide (CO).
- Carbon dioxide (CO_2).
- Hydrogen (H_2).
- Methane (CH_4).
- Nitrogen (N_2).

3.2 Block Diagram

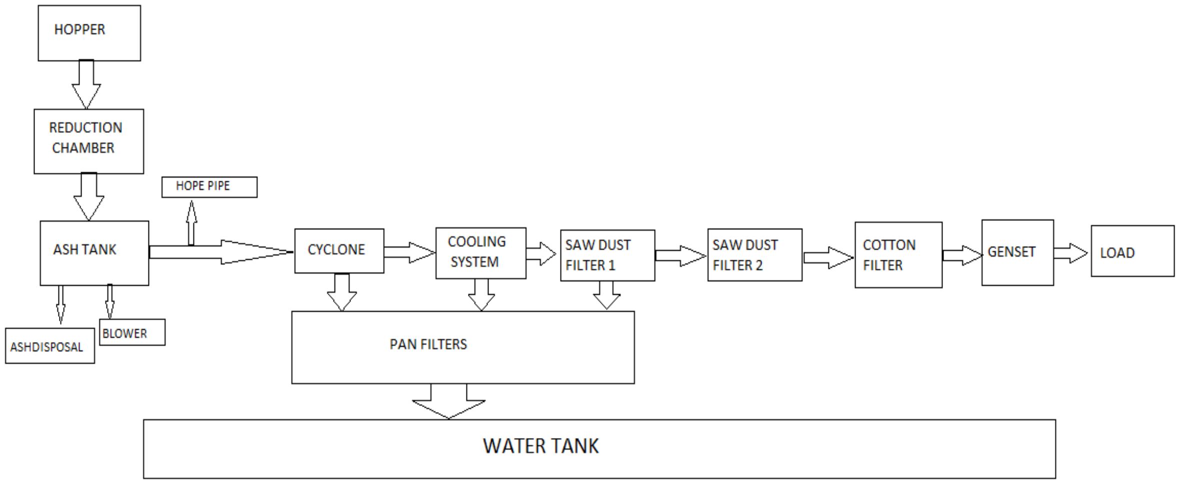

Fig-5 Downdraft gasifier

3.3 Components Of Downdraft Gasifier
- Ignition pot
- Hopper
- Reduction Chamber
- Ash tray
- Cyclone
- Cooling Tower
- Saw Dust Filters
- Pan Filter
- Cotton Filter
- Water Tank
- Engine

3.4 Operation Of Downdraft Gasifier.

Because of the low tar content downdraft gasifier has been very successful for operating engines.In the downdraft gasifier air contacts the pyrolyzing biomass before it contacts the char and supports a flame similar to the flame which is generated the heat from the burning volatiles maintains the pyrolysis and after this phenomenon occurs with in a gasifier and the limited air supply in the gasifier is rapidly expended, so that the flame gets richer as pyrolysis proceeds and at the end of the pyrolysis zone and the gases consist mostly of about equal parts of COz, HzO, CO, and Hz and we call this flame in a limited air supply "flaming pyrolysis" and the flaming pyrolysis produces most of the combustible gases generated during downdraft gasification and simultaneously consumes 99% of the tars and it is the principal mechanism for gas generation in downdraft gasifier[12].

3.5 Instrument Using During Experiment
- Hot wire anemometer
- Pressure differential meter (PDM).
- Digital temperature indicator.

- Weighing balance.
- Voltmeter.
- Wattmeter.
- Frequency meter.
- Energy meter.
- Gas Chromatograph**.**

3.6Methodology Adopted For Performance Test

- Moisture Calculation.
- Mass balance.
- Energy balance.
- Elemental balance.
- Temperature measurement.
- Pressure drop measurements.
- Electrical Output.

3.6.1 Moisture Calculation

Moisture Content refers to water that is contained within a piece of wood, but in not part of the wood molecules. We often refer to it as "free water".

Moisture content is expressed on either a wet basis Moisture content is expressed on either a wet basis or dry basis. This refers to whether the dry or wet weight of the wood is used as the denominator.

3.6.2 Mass Balance

The biomass gasifier, gas cooling equipment, , gas cleaning equipment and the engine are considered as a single system for this analysis and the mass balance analysis was carried out by estimating the mass flow of the materials across the system boundary and this includes balancing of different output materials for example ash, tar and producer gas and input materials such as fuel wood and air [13].

3.6.3 Energy Balance

The energy balance analysis was carried out by estimating the energy content of the input and output materials and the fuel wood samples were collected from each lot of fuel wood fed into the gasifier. Proximate analysis of the fuel wood samples was carried out to find out ash content and moisture content and the ultimate analysis of the fuel wood samples was carried out to find out Carbon, Hydrogen, Oxygen and Nitrogen content and the energy input to the system was estimated based on total fuel wood consumption and its calorific value and the gas samples were collected and analyzed using a gas chromatograph, to obtain the gas components of the producer gas and the calorific value of the producer gas is estimated based on the combustible gas components of the producer gas[14].

3.6.4 Elemental balance

A detailed elemental balance analysis of the input materials and the output products was carried out for evaluating the performance of the gasifier system and the elemental balance analysis had been carried out by estimating the individual elements present in the input materials and the output products and the results of the ultimate analysis of the fuel wood analysis of the gas components of the producer gas are used to estimate the elemental balance. Elemental contribution of the fuel wood and air is estimated by using the three steps, as known below[15].

i) Estimation total quantity of air fed for gasification of the fuel wood and the total weight of the fuel wood fed into the gasifier and
ii) Estimation of the individual element and their individual weight contributed from the input material i.e. air, fuel and wood.
iii) Estimation of the individual element's mass contribution by adding the identical elements present in the air, fuel and wood.

3.6.5 Temperature Measurement

In order to estimate the energy balance the gas and air temperature was monitored at several locations in the system and the gas and the air temperature was monitored regularly throughout the experiment at an interval of one hour and the temperature of producer gas and air measured at various locations of the heat exchanger [16].

3.6.6 Electrical Output

The electrical output of the biomass gasifier based power generation system was monitored throughout the period of the test run and the performance of the generator with the summary of the electrical power output will be monitored[16].

3.7 Materials Used In Downdraft Gasifier

- Wood chips[50mm*50mm,rectangle shape].
- Rice Husk.
- Coconut Shell.
- Brequettes.

IV. Conclusion

- The content of hydrogen in the producer gas increases with moisture content for all the materials considered but almost in a linear fashion.
- The carbon monoxide content in the producer gas decreases with moisture content for all the materials considered which decreases the power output.
- The calorific value of the producer gas decreases with the increase in moisture content for all the raw material used (wood chips, rice husk etc)
- Suited for Rural areas because of CO_2 emission..
- Maintenance is important because of dust,tar and the waste gas which is stored in filters.

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