Design and Development of Downdraft Gasifier for Rural Area

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ABSTRACT

Biomass is the main source of energy for a large number of small, rural, and cottage industries along with the majority of rural households. The biomass-consuming industries can be divided into two categories, namely traditional industries and new or potential industries. Traditional biomass-based industries are essentially rural cottage and small scale industries. These industries depend predominantly on biomass fuels such as wood, agricultural residues, and animal dung because biomass is cheap and its supply is assured. Biomass energy is used in these industries for direct heating (firing of bricks, lime), indirect firing (drying, baking), boiling, steam raising and distillation. The production of generator gas (producer gas) called gasification, is partial combustion of solid fuel (biomass) and takes place at temperatures of about 1000 C. The reactor is called a gasifier. The combustion products from complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. However in gasification where there is a surplus of solid fuel (incomplete combustion) the products of combustion are combustible gases like Carbon monoxide (CO), Hydrogen (H2) and traces of Methane and non useful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a glowing layer of charcoal. Thus the key to gasifier design is to create conditions such that a) biomass is reduced to charcoal and, b) charcoal is converted at suitable temperature to produce CO and H2.Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H2) and traces of Methane (CH4).This mixture is called producer gas. Producer gas can be used to run internal combustion engines (both compression and spark ignition), can be used as substitute for furnace oil in direct heat applications and can be used to produce, in an economically viable way, methanol – an extremely attractive chemical which is useful both as fuel for heat engines as well as chemical feedstock for industries

Think of the 18 000 Indian villages that will continue to be without electricity for at least the next 10 years. Though they fall under the government's rural electrification programme, it is not feasible at present to connect them to the grid. Then, there are other 62 000 villages that are still waiting to be wired and in villages that are already wired, supply continues to be erratic. To electrify rural India so as to usher in development uniformly is an uphill task

India being a large agrarian economy, biomass – wood, agricultural residues, animal dung, etc. – is available in enormous quantities. And, hence, over 40% of India's total energy requirement is met through biomass burning. However, biomass burning has been characterized with energy inefficiency and environmental hazards. Working towards a sustainable solution to the energy scarcity in rural India, researchers have arrived at a technological innovation to exploit the vast biomass resource and generate power in an environment-friendly and profitable proposition. Biomass-based power generation systems for rural applications could effectively make up for the absence of grid electricity supply in many remote areas.

1. THEORY OF GASIFIER

A gasifier is a reactor that converts biomass into clean gaseous fuel called producer gas (having calorific value of the order of 1000–1200 kilocalories per normalized cubic meter). biomass gasifier system optimally utilizes biomass for power generation. It consists of a downdraft gasifier, a gas-cleaning train, and an engine. The technological innovation provided users with the option of dual-fuel operation. The existing diesel genset could run on both diesel and producer gas, instead of running only on diesel. The producer gas is fed into the diesel engine to let the engine operate in a dual-fuel mode, thereby reducing diesel consumption by more than 70%.

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A. Types of Gasifiers

Since there is an interaction of air or oxygen and biomass in the gasifier, they are classified according to the way air or oxygen is introduced in it. There are three types of gasifiers (Figure 2); Downdraft, Updraft and Cross draft. And as the classification implies updraft gasifier has air passing through the biomass from bottom and the combustible gases come out from the top of the gasifier. Similarly in the downdraft gasifier the air is passed from the tuyers in the downdraft direction.

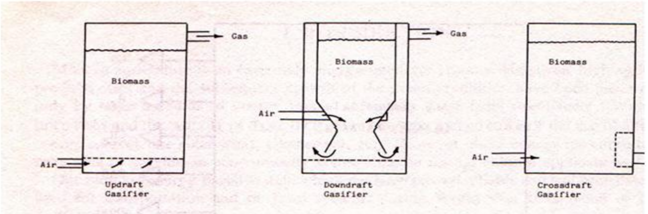


FIGURE 2. Various types of gasifiers.

1.UD Gasifier **2.DD Gasifier** **3.CD Gasifier**

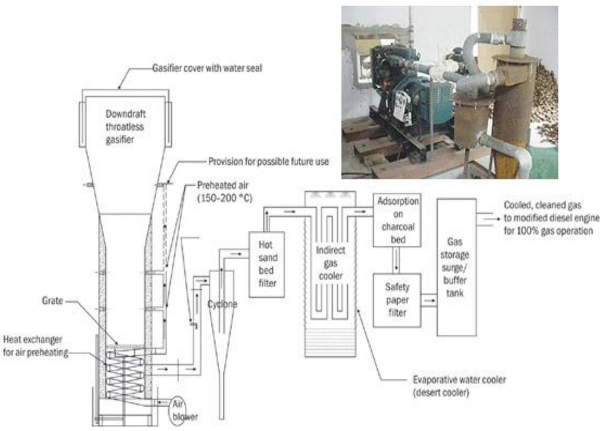
Process Zones

Four distinct processes take place in a gasifier as the fuel makes its way to gasification. They are :

1. **Drying of fuel Zone**
2. **Pyrolysis** Zone – a process in which tar and other volatiles are driven off
3. **Combustion Zone**
4. **Reduction Zone**

Gasifier system comprises a downdraft throat-less gasifier, has multi-fuel capability and end-use flexibility. Fuel wood or briquettes produced from agricultural residues can be used in this gasifier. The throat less design makes for smooth fuel movement, with the gasifier allowing comparatively larger pieces of wood or fuel briquettes. Water seal arrangement with continuous grate-shaking mechanism simplifies ash and char removal without shutting down the system, thus enabling long uninterrupted operation. Entry of preheated air at two levels helps obtain good quality gas, with low impurities in raw gas. This also reduces the load on the gas-cleaning system. Induction of a cooling tower minimizes water requirement for gas cleaning and also reduces the quantities of tar-laden water to be disposed of Village applications, such as water pumps for irrigation can immensely benefit from the new technology. It can also be a boon to many agro-processing enterprises (those working with coffee, cashew, tobacco, plywood, and so on) that can recycle their biomass by-products to generate power. Using this technology, the tea industry in South India alone has the potential of generating 2000 megawatt of power from its biomass by-products.

The available biomass in the country (excluding animal residues) can support electrical power plants of 16 000 megawatts.



Tapping of this potential will be beneficial for the individual and also for the country The biomass-based gasifier technology carries an environment-friendly and sustainable solution to the power crisis in rural India. It can reduce the use of fossil fuels in village applications. The technology can recycle bio-waste, be localized, and made available on demand without the need for separate storage. It also provides livelihood opportunities to the local population through various activities—biomass generation, processing, and operation of the plant.The electricity produced from a biomass-based gasifier system can be used for lighting houses, powering irrigation pumps, and operating machines such as chillers. The table below explains the economics of a biomass based power plant as compared to power plants based on other renewable energy sources.Economics of power plants (of 10-100 kilowatt capacity) based on biomass and other renewable energy source.

Reaction Chemistry

The following major reactions take place in combustion and reduction zone12.

1. Combustion zone

The combustible substance of a solid fuel is usually composed of elements carbon, hydrogen and oxygen. In complete combustion carbon dioxide is obtained from carbon in fuel and water is obtained from the hydrogen, usually as steam. The combustion reaction is exothermic and yields a theoretical oxidation temperature of 14500C14. The main reactions, therefore, are:

$C + O_2 = CO_2$ (+ 393 MJ/kg mole) (1)

$2H_2 + O_2 = 2H_2O$ (- 242 MJ/kg mole) (2)

Fuel	Gas. Meth.	CO	H2	CH4	CO2	N2	Calorific value MJ/m3
Charcoal	DD	28-31	5-10	5-10	1-2	55-60	4.60-5.65
Wood with 12-20% moisture content	DD	17-22	16-20	2-3	10-15	55-50	5.00-5.86
Wheat straw pellets	DD	14-17	17-19	-	11-14	-	4.5
Coconut husks	DD	16-20	17-19.5	-	10-15	-	5.8
Coconut shells	DD	19-24	10-15	-	11-15	-	7.2
Pressed Sugarcane	DD	15-18	15-18	-	12-14	-	5.3
Charcoal	UD	30.00	19.70	-	3.6	46	5.98
Corn cobs	DD	18.60	16.50	6.4	-	-	6.29
Rice hulls pelleted	DD	16.10	9.6	0.95	-	-	3.25
Cotton stalks cubed	DD	15.7	11.7	3.4	-	-	4.32

2. Reaction zone

The products of partial combustion (water, carbon dioxide and uncombusted partially cracked pyrolysis products) now pass through a red-hot charcoal bed where the following reduction reactions take place12.

$C + CO_2 = 2CO$ (- 164.9 MJ/kg mole) (3)

$C + H_2O = CO + H_2$ (- 122.6 MJ/kg mole) (4)

$CO + H_2O = CO + H_2$ (+ 42 MJ/kg mole) (5)

$C + 2H_2 = CH_4$ (+ 75 MJ/kg mole) (6)

$CO_2 + H_2 = CO + H_2O$ (- 42.3 MJ/kg mole) (7)

Reactions (3) and (4) are main reduction reactions and being endothermic have the capability of reducing gas temperature. Consequently the temperatures in the reduction zone are normally 800-10000C. Lower the reduction zone temperature (~ 700-8000C), lower is the calorific value of gas.

3. Pyrolysis zone

Wood pyrolysis is an intricate process that is still not completely understood14. The products depend upon temperature, pressure, residence time and heat losses.

However following general remarks can be made about them. Upto the temperature of 200^0C only water is driven off. Between 200 to 280^0C carbon dioxide, acetic acid and water are given off. The real pyrolysis, which takes place between 280 to 500^{0}C, produces large quantities of tar and gases containing carbon dioxide. Besides light tars, some methyl alcohol is also formed. Between 500 to 700^{0}C the gas production is small and contains hydrogen. Thus it is easy to see that updraft gasifier will produce much more tar than downdraft one. In downdraft gasifier the tars have to go through combustion and reduction zone and are partially broken down. Since majority of fuels like wood and biomass residue do have large quantities of tar, downdraft gasifier is preferred over others. Indeed majority of gasifiers, both in World War II and presently are of downdraft type.

Compositions of Producer gas from various fuels

Finally in the dr Finally in the drying zone the main process is of drying of wood. Wood entering the gasifier has moisture content of 10-30%. Various experiments on different gasifiers in different conditions have shown that on an average the condensate formed is 6-10% of the weight of gasified wood14. Some organic acids also come out during the drying process. These acids give rise to corrosion of gasifiers.

2. CONCLUSIONS

1) Biomass gasification offers the most attractive alternative energy system for agriculture purpose.
2) Most preferred fuels for gasification have been charcoal and wood however biomass residues are the most appropriate fuels for the on-farm systems & offer the greatest challenge.
3) Very limited experience has been gained in gasification of biomass residues
4) Biomass gasification offers the most attractive alternative energy system for agriculture purpose.
5) Most preferred fuels for gasification have been charcoal and wood however biomass residues are the most appropriate fuels for the on-farm systems & offer the greatest challenge.
6) Very limited experience has been gained in gasification of biomass residues
7) In this era of petroleum fuel shortage, this gasifier may play the key role in Industrial belt, transportation belt and Power generation belt.
8) By the means of usage of gasifier, wastes like coconut husk/shells, rice husk, pressed sugarcane which would have been otherwise polluted the atmosphere may be recycled to produce the valuable fuel and gas.
9) Raw materials required for the gasifier is readily and chiefly and abundantly available or can be made available
10) This would be the environment freely converters.

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