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Innovative Biomass Energy System and a remedy for Green House Gas effects

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ABSTRACT

Contemporary Global interest is shifting towards alternate energy systems with the diminishing reserves of fossil fuels like petroleum, diesel, coal etc, to replace them by adopting Biomass plants. Developing countries like India also encouraging such projects. Biomass energy systems are two types, of which one of the systems utilizes wet municipal solid waste for generating energy while the other system uses dry agriculture waste material for producing energy. However, both the systems liberate considerable volumes of gases like nitrogen, carbon monoxide, carbon dioxide etc., as by products. Present study is taken up to make complete use of gases including the above mentioned by products for energy generation. The uncontrolled liberation of gases can be consumed by their proper treatment with suitable bacteria. These bacteria convert the high volumes of nitrogen to ammonia liberating hydrogen which is a high calorific energy gas. The remaining gaseous byproducts are directly send to genset to produce energy. The process is enviconment friendly that prevent air pollution and even soil polution by means of complete utilization of solid waste of any kind.

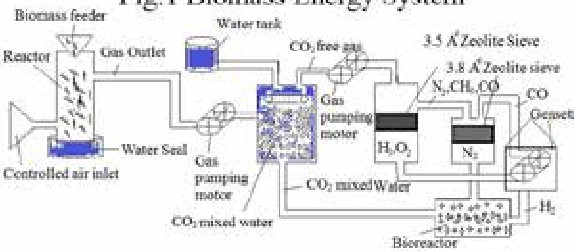
KEYWORDS :

Introduction

In modern days the human civilization is completely dependent on energy, consequently the non-renewable energy resources such as fossil fuels are continuously depleting. So there is great need to find out an alternate to prevent the imminent scarcity. Such an alternative, sustainable energy resource can be achieved by Bioenergy projects. India is an agricultural country which could generate huge quantities bio mass, municipal solid waste. if we use this biomass in efficient manner at least up to some extent we can solve the problem of energy (Dutta, R. et al .,1981). The procedure of energy production from the dry and wet solid municipal waste involves steps like combustion, reduction, pyrolysis, collection of gas and filling of the gas. In the conventional bioenergy systems various gases evolved as byproducts in the process of energy production such as Carbon monoxide, Carbon-di-oxide, Nitrogen etc., into the atmosphere, causing air pollution. This can be subsided by the proper treatment of these by products with suitable bacteria. Hydrogen and carbon monoxide are directly used as producer gas, but nitrogen is an inert gas, though it will not harm the environment, the volume of the nitrogen emitted by a conventional bioenergy system into the atmosphere is more than 48% to 50%. The nitrogen thus evolved can be treated with bacteria that convert the nitrogen into ammonia, liberating hydrogen, which is a high calorific energy producer gas.

Methodology

Fig. 1 Biomass Energy System



In the present study the biomass sized to 1.2 mm to 0.75 mm by the pre processing system which enhances H_2 and CO contents along with good yield of producer gas and minimized CO_2 (Luo,S et al.2009) as it is passed through the different stages like 1)Drying, 2) Combusion, 3)Reduction 4)Pyrolysis, and 5)Enzymatic reactor/Bioreactor (Fig.1). Drying of the biomass removes the moisture from the solid waste. Combustion process liberates CO_2 mixed with water in the form of steam. Partial combustion of carbon-dioxide and other products subjected to reduction to produce CO. Pyrolysis produces larger CO_2 and tar along with little amounts of methyl alcohol. Total N_2 released during the process is sent to the bioreactor which is filled with nitrogen converting bacteria. The bacteria convert the N_2 into ammonia liberating high calorific H_2. The sized biomass is fed through biomass feeder into the reactor, where the biomass is burnt under controlled air inlet to produce gas and the water seal at the bottom of the reactor prevent gases to retain within the reactor. The gas then mixed with water to separate the CO_2. The CO_2 free gas is passed into two different sieves to filter H_2, O_2 and N_2. The N_2 gas is sent to the bioreactor filled with bacteria where the bacteria convert total N_2 into Ammonia liberating high calorific H_2.

Results and discussion

The method of generating the gas is called gasification; it is generated by the partial combustion of the biomass under controlled air or oxygen at a temperature of about 1000c.There are three types of bio gasifiers such as Down draft gasifier, Updraft gasifier and Cross draft gasifier based on the Air or oxygen interaction. In general the gasifier gas contains hydrogen, carbon, methane, carbon dioxide and nitrogen.

Gas composition	
Hydrogen	18-20%
Carbon	18-20%
Methane	1-2%
Carbon dioxide	12-14%
Nitrogen	45-48%

1. Drying

Collected biomass from different sources may contains high moisture, without drying we cannot obtain a desired range of water content for the gasification process .drying is an energy based system which may affect the gasification process and efficiency. However, in the case of gasification, waste heat of the system can decrease the moisture content of the biomass and results for overall increase of efficiency Perforated bin dryers, and conveyor dryers and rotary cascade dryers have been used to dry biomass (Cummer, K.R, et al, 2002) in generating combined heat and power, biomass moisture should be as low as possible to increase the overall efficiency and decrease the net cost of electricity. However, for low moisture raw biomass (less than 10%) drying stage may not be needed (Brammer et al, 2002). In this stage the bio mass or MSW is passed from the top of the rector , get heated in the first stage results for loss of moisture and get ready for the next stage of process, even though the stages are overlapped with each other; each phase of stage differ from chemical and thermal reactions.

Reaction Chemistry

The following major reactions take place in the process of gasification (Mansaray.K.G et al, 1997; Kumar,A., et al, 2008; Varhegyi,G., et al, 1997; Biagin,E., et al, 2006)

CH_xO_y (biomass) + O_2 (21% of air) + H_2O (steam) =

CH_4 + CO + CO_2 + H_2 + H_2O (unreacted steam) + C (char) + tar- (1)

2C + O_2 = 2CO (partial oxidation reaction)--(2)

C + O_2 = CO_2 (complete oxidation reaction)--(3)

C + $2H_2$ = CH_4 (hydrogasification reaction)--(4)

CO + H_2O = CO_2 + H_2 (water gas shift reaction)--(5)

CH_4 + H_2O = CO + $3H_2$ (steam reforming reaction)--(6)

C + H_2O = CO + H_2 (water gas reaction)--(7)

C + CO_2 = 2CO (Boudourd reaction) –8

2. Combustion zone

The biomass substance usually composed of elements carbon, hydrogen and oxygen. In total combustion Carbon dioxide is obtained from carbon of the biomass and water in the form of steam usually from hydrogen of biomass. The combustion reaction are exothermic and yields a theoretical oxidation temperature of 1450^0C The main reactions are:

C + O_2 = CO_2 (+ 393 MJ/kg mole) (9)

$2H_2$ + O_2 = $2H_2O$ (- 242 MJ/kg mole) (10)

3. Reduction zone

The output of partial combustion (carbondioxide,water and uncombusted partially cracked pyrolysis product) on passing through a red –hot charcoal bed results for the following reduction reactions

C + CO_2 = 2CO (- 164.9 MJ/kg mole) (11)

C + H_2O = CO + H_2 (- 122.6 MJ/kg mole) (12)

CO + H_2O = CO + H_2 (+ 42 MJ/kg mole) (13)

C + $2H_2$ = CH_4 (+ 75 MJ/kg mole) (14)

CO_2 + H_2 = CO + H_2O (- 42.3 MJ/kg mole) (15)

Reactions (11) and (14) are main reduction reactions and being endothermic have the capability of reducing gas temperature. Consequently the temperatures in the reduction zone are normally 800-1000^0C. Lower the reduction zone temperature (~ 700-800C), lower is the calorific value of gas.

4. Pyrolysis zone

Pyrolysis output products depend upon size of feed, temperature, pressure, residence time and heat losses. However following general remarks can be made about system. Water is driven at a temperature of 200^0C.Carbon dioxide; acetic acid and water are given off in the pyrolysis up to 280^0 c. From 280 to 500^0 c produces lager gas amount of carbon dioxide and tar along with little amounts of methyl alcohol but the process in between 500 to 700 C produces hydrogen.Updraft gasifier will produces more tars than the down draft gasifiers, In the down draft gasifiers the tar produced will go to further brake down during the process in combustion and reduction phase with more gas.

Gasifiered gas is affected by processes as mentioned and may variation in the production of gases from different biomass sources and types of gasifier design and result for different calorific values.

Fuel	Gasifier type	Volume percentage					Calorific value	Reference
		CO	H_2	CH_4	CO_2	N_2		
Charcoal	Down-draft	28-31	5-10	1-2	1-2	55-60	4.60-5.65	SERI
Wood with 12-20% moisture content	Down-draft	17-22	16-20	2-3	10-15	55-50	5.00-5.86	SERI
Wheat straw pellets	Down-draft	14-17	17-19	-	11-14	-	4.50	Hoblund et.al
Coconut husks	Down-draft	16-20	17-19.5	-	10-15	-	5.80	Hoblund et.al
Coconut shells	Down-draft	19-24	10-15	-	11-15	-	7.20	Hoblund et.al
Pressed Sugar-cane	Down-draft	15-18	15-18	-	12-14	-	5.30	Hoblund et.al
Charcoal	Up-draft	30	19.7	-	3.6	46	5.98	Skov et.al
Corn cobs	Down-draft	18.6	16.5	6.4	-	-	6.29	13 CEC report
Rice hulls pelleted	Down-draft	16.1	9.6	0.95	-	-	3.25	CEC report
Cotton stalks cubed	Down-draft	15.7	11.7	3.4	-	-	4.32	CEC report

The maximum dilution of the gas done by the nitrogen and there is nearly 50% -60% of nitrogen

Purification and Trapping of nitrogen

The temperature of gas coming out of gasifier is normally between 300-500^0C. This gas has to be cooled in order to raise its energy density. Various types of cooling equipment have been used to achieve this. Most coolers are gas to air heat exchangers where the cooling is done by free convection of air on the outside surface of heat exchanger. Since the gas also contains moisture and tar, some heat exchangers provide partial scrubbing of gas (Skov et.al 1974). Thus ideally the gas going to an internal combustion engine should be cooled to nearly ambient temperature.

In the dry category are cyclone filters. They are designed according to the rate of gas production and its dust content(Chemical Engineering Hand book ,Perry.R.H 1973). The cyclone filters are useful for particle size of 5 μm and greater(Chemical Engineering Hand book ,Perry.R.H 1973). Since 60-65% of the producer gas contains particles above 60 μm in size the cyclone filter is an excellent cleaning device .After passing through cyclone filter the gas still contains fine dust, particles and tar. It is further cleaned by passing through either a wet scrubber or dry cloth filter. In the wet scrubber the gas is washed by water in countercurrent mode. The scrubber also acts like a cooler, from where the gas goes to cloth or cork filter for final cleaning. Since cloth filter is a fine filter, any condensation of water on it stops the gas flow because of increase in pressure drop across it. Thus in quite a number of gasification systems the hot gases are passed through the cloth filter and then only do they go to the cooler. Since the gases are still above dew point, no condensation takes place in filter.

Molecular sieves

The output gas is further purified and nitrogen trapped by means of molecular sieves of synthesized zeolite (Ragaranjan, D.K., et al, 2013) . The molecular sieve process for trapping of nitrogen takes the advandatage of a new type of molecular sieve that the unique ability to adjust pore size openings with in an accuracy of 0.1 angstom .The pore size is precisely adjusted in the manucacturing process and allows the production of a molecular sieve with a pore size tailored to size selective separation

The molecular kinetic diameter (Jingui Duan et.al.,2013)

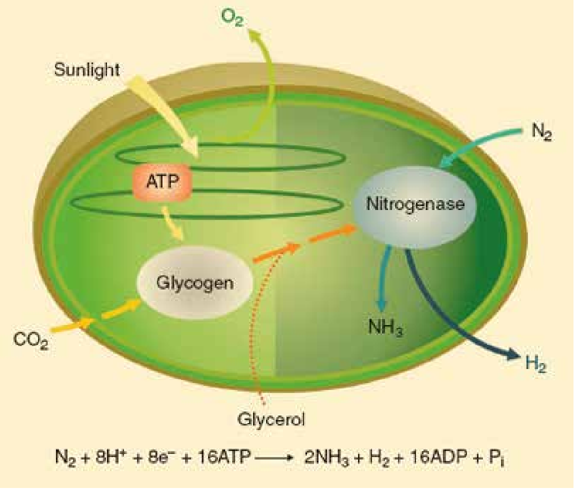
Gas	Kinetic diameter A^0
H_2	2.89
CO_2	3.3
CO	3.76
N_2	3.64
O_2	3.46
CH_4	4.0

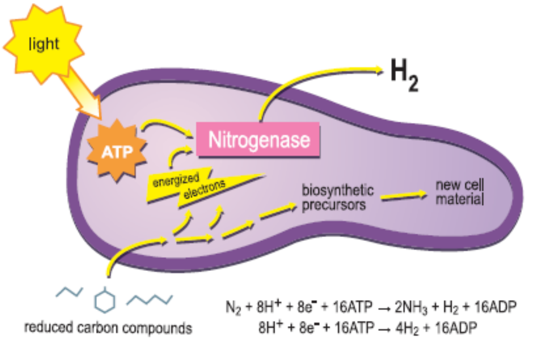
Nitrogen and other molecular diameter are approximately as above. The gas mixers are passed through the different seized sieves to collect and trap the nitrogen . In the first stage the gas is allowed to pass through a sieve of 3.5 A^0 which separates nitrogen and CO by allows other gases to pass next stage , the separated gas is again passed through the sieve of pore size 3.7 A° which separates CO by along nitrogen to pass through and is fed to a bio reactor for further fuel enhancement. The by passed co is again mixed with the first stage gases and fed into the IC engines to produce electricity.

5. Bioreactor

Photosynthetic microbes can produce the clean burnig fuel hydrogen gas(hydrogen) of using one of nature`s most plentiful resouses,sunlight (Das, D et al, 2001; Gest.H.,1950; Prince, R.C, et al., 2005) A major route for hydrogen production is biological nitrogenfixation (Geat H,1950, Hillmer,1977, Prince,2005)

The nitrogen and CO_2 are fed in to the bioreactor where microbs like nitrogenases, cyanothece (santi et al, 2013) are able to produce hydrogen aerobically because its metabolic processes by acircadian clock, it photosynthesizes during the day and fixes carbon which it store as glycogen and at night it begins fixing glycogen as an energy source to convert N_2 to NH_3 with H_2 as by product, additional H_2 can also produced by the supply of tapped CO_2 form the above process which acts as carbon sources.





The produced h2 is tapped and fed in to the IC engine , which is an added fuel and resulting for high power generation with a with a good fertilizer .

Conclusions

Conventional gasification processes emit up to 50% of Nitrogen into atmosphere. The procedure in the present study will serve better to use complete N_2 for producing high calorific fuel in the form of H_2 in addition to the ammonium which is an important fertilizer for agriculture. The process is more eco-friendly and intended to utilize high percentage of total biomass feed without causing any pollution. This process is proved to consequent green and pollution free energy producer.

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