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Exergy Analysis: Hydrogen Production from Biomass Gasification

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Abstract:- Aim: **This work aims at performing the exergy analysis of Hydrogen Produced from Biomass gasification. Exergy analysis were done on two system to check which one gives the better efficiency.**

Hydrogen is considered to be the important energy carrier for the future, and biomass is very reliable source for the sustainable production of hydrogen. Biomass Gasification is demanding choice for the production of hydrogen gas. The biomass is fed into gasifier at an operating range of 1000-1500 K. 5 kg/s of steam at 500 K is used as gasification medium. Hydrogen production can be improved by the amount of steam and quantity of biomass fed into the gasifier. For the reference environment, the temperature was 298 K and the pressure was 1 atm. Two cases were studied, one for HT shift reactor and other was LT shift reactor. After carrying out the exergetic analysis the exergetic efficiency for the two were found be 1.23% and 1.22 %for HT shift reactor and LT shift reactor respectively.

Keywords: ***Exergy; Biomass, Gasifier, hydrogen, assessment, analytics***

1-INTRODUCTION

The demand for renewable energy is growing day by day because of the increase of global warming and there is also declining reserve of fossil fuel. Biomass is said to be the third energy resource after coal and oil. Use of Biomass can give significantly less CO2 gas therefore causing less impact on global warming. Biomass is a solid form, to convert and make it more energy efficient. So, gasification is a process involved which converts carbon containing feed stock into synthetic gas including hydrogen. Gasification is an endothermic process. Therefore, heat is needed to sustain the gasification process. Gasification is a complex process and is influenced by number of factors such as temperature, pressure in gasifier, feedstocks quality etc. Gasification involves following five process. They are

1. Drying
2. Pyrolysis
3. Combustion
4. Cracking
5. Reduction

To make an approach for the gasification procedure of biomass, it is essential to know biomass properties, specifically, the proximate and a definitive examination and its heating quality. The biomass has higher carbon–hydrogen proportion and essentially bring down sulphur and nitrogen substance. The lower sulphur and nitrogen substance make possibilities to toxins are unbiased or low. The biomass is viewed as unbiased asset with respect to CO2 life cycle. Making an approach for a hydrogen generation from biomass gasification through a parametric review means to compute hydrogen from gasification measure of biomass in existing measure of gasification operator lead the gasification response and heat required. The later parameter is taken in thought by accepting the gasifier is self-heated. The gasifier is the main part for the process of gasification. t is renewable and neutral concerning to carbon dioxide emission issue. The level of utilization of biomass to produce hydrogen depends on economics and availability of the necessary technology. Gasification of biomass to produce hydrogen as energy carrier is a part of the effort to combat this threat. The gasification steps are hypothetically displayed in arrangement however there is no sharp limit amongst them and they frequently cover. The gasification response on a fundamental level includes carbon, carbon monoxide, carbon dioxide, hydrogen and methane. Hydrogen is required to be the most critical vitality bearer in a supportable vitality framework. Basically, we may very well consider gasification smouldering a match, however intruding on the procedure by funnelling off the reasonable gas we see ideal over the match, not giving it a chance to blend with oxygen and finish burning. On the other hand, we may consider it running our motor greatly rich, making enough heat to break separated the crude fuel, yet without enough oxygen to finish ignition, therefore sending burnable gasses out the fumes. This is the manner by which a hot rod gets blazes out the fumes funnels.

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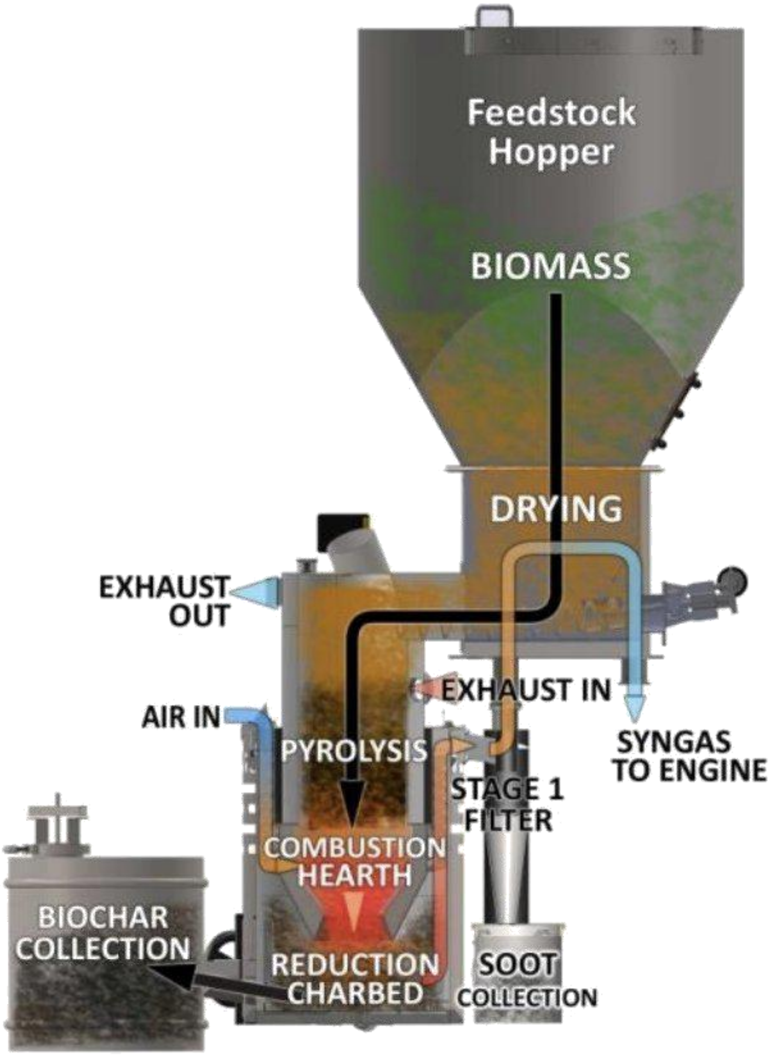

Fig 1: Layout of a gasification plant

Reference: Accessed online (6-3-2017) on http://insights.globalspec.com/article/1957/startup-aims-tocommercialize-biomass-gasifiers

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2-PROCESS INVOLVED IN GASIFICATION

2.1. Drying

Drying is done to remove moisture from the biomass before pyrolysis is done. Moisture should be removed from fuel before any process take places at 100 ∞ C. The water will get vaporised at some point form the fuel when it is subjected to high temperature process. When the fuel is high in moisture then there is higher possibility of not getting the clean gas as output. This is one of the common reason for the failure of producing cleaner gas.

2.2. Pyrolysis

Pyrolysis is a process in which raw biomass is subjected to heat in absence of heat to decompose into charcoal and other liquids and gaseous. When the temperature rises above 240 ∞ C the raw biomass starts to decomposes with heat very fastly. The biomass decomposes into a combination of solids, liquids and gasses. The solid remains are called charcoal. The gaseous and liquid are together called Chars. The gaseous and the liquid produced are originally the small fragments of the biomass that was broken due to heat. These fragments are C, H and O molecules which are very reactive. The main aim of gasification is to breakdown this wide varieties in the form of hydrogen and carbon monoxide. Both of these two gaseous can be burned easily.

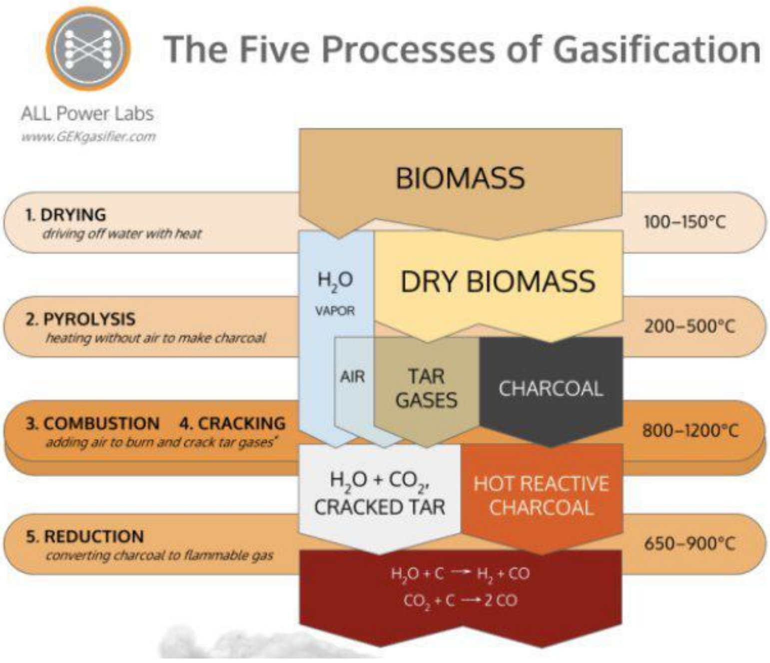

Fig 2: Five processes of gasification Reference: Accessed online

(6-3-2017) http://www.allpowerlabs.com/gasification-explained

2.3. Combustion

Combustion is the main procedure of the Five Processes of Gasification; at last, the greater part of the heat that drives drying, pyrolysis, and reduction comes either specifically from burning, or is recuperated in a roundabout way from ignition by heat trade forms in a gasifier. Burning can be energized by either the tar gasses or roast from Pyrolysis. Diverse reactor sorts utilize either or both. In a downdraft gasifier, we are attempting to blaze the tar gasses from pyrolysis to create heat to run decrease, and in addition the CO2 and H2O to lessen in reduction. The objective in ignition in a downdraft is to get great blending and high temps so that every one of the tars are either singed or broken, and in this way, won't be available in the active gas. The singe informal lodging contributes a generally little to the transformation of untidy tars to helpful fuel gasses. Taking care of the tar issue is for the most part an issue of tar splitting in the burning zone.

2.4. Cracking

Cracking is the way toward separating vast complex atoms, for example, tar into lighter gasses by introduction to heat. This procedure is significant for the creation of clean gas that is perfect with an inward ignition motor since tar gasses gather into sticky tar that will quickly foul the valves of a motor. Cracking is likewise important to guarantee appropriate ignition on the grounds that total burning just happens when flammable gasses completely blend with oxygen. Over the span of burning, the high temperatures created decay the extensive tar particles that go through the ignition zone.

2.5. Reduction

Reduction is the procedure removal of oxygen particles off ignition results of hydrocarbon (HC) atoms, in order to give back the particles to structures that can blaze once more. Lessening is the immediate turn around procedure of ignition. Burning is the blend of ignitable gasses with oxygen to discharge warm, delivering water vapour and carbon dioxide as waste items. Lessening is the expulsion of oxygen from these waste items at high temperature to create ignitable gasses. Ignition and Reduction are equivalent and inverse responses. Actually, in most blazing situations, they are both working at the same time, in some type of element harmony, with rehashed development forward and backward between the two procedures.

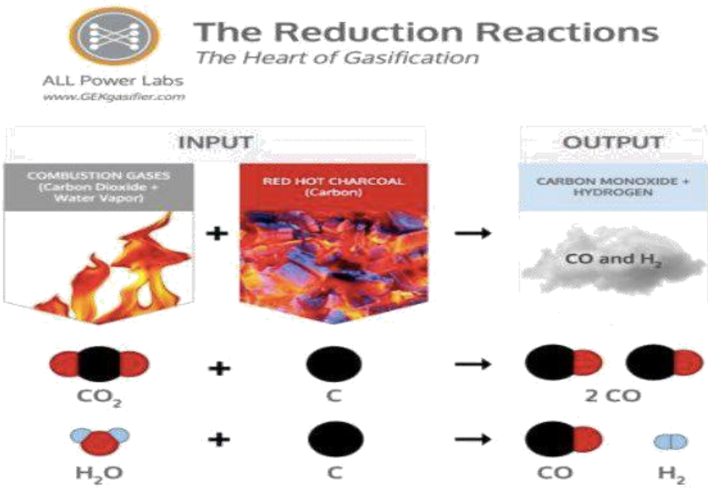

Fig 3: The Reduction Reactions

Reference: Accessed online (6-3-2017)
http://www.allpowerlabs.com/gasification-explained

3-MODELING A BIOMASS GASIFICATION

Modelling of the considered gasification systems is based on literature information. The ecological conditions in the models are set at a pressure of 1.01325 bar and a temperature of 15 C. All hydrogen plant outlines are The procedures depend on a heat contribution of 10 MW. For every hydrogen plant a consistent state show has been implicit Cycle-Tempo.

4-GAS CLEANING

Keeping in mind the end goal to deliver 99.99% pure hydrogen from the maker gas originating from the gasifier, it should be cleaned and prepared. The maker gas from the gasifier contains basically hydrogen, carbon monoxide, carbon dioxide and methane. Other than the fundamental segments, the gas contains additionally minor pollutions, similar to particulates, tar, soluble bases, incandescent light and sulphur mixes. The primary segments of the maker gas must be changed over into hydrogen beyond what many would consider possible and the rest of the parts must be evacuated all together get practically immaculate hydrogen. In any case, this gas preparing is just conceivable in the wake of expelling first the impurities to adequately low levels to empower legitimate operation of the gas handling reactors. Two techniques for gas cleaning are considered for every gasification procedure: low temperature gas cleaning (LTGC) and high temperature gas cleaning (HTGC).

4.1-LOW TEMPERATURE GAS CLEANING

The gas, which leaves the gasification area, is initially cooled to around 120 C. The cooling adds to the cleaning, displayed in the program Cycle-Tempo an in-house created stream sheeting program particularly intended for the assessment of vitality transformation frameworks. The hydrogen created is 99.99% original, which can be connected in different applications.

since soluble bases will likely consolidate at 600 C on to the entrained particulates. At that point the gas is gone through a sack channel, to expel the particulates together with the dense antacids. After the channel the gas is sustained to a stuffed bed containing zinc oxide, which is utilized to adsorb the hydrogen sulphide in the gas. The measure of sulphur in wood is low, in this way cleaning in a zinc oxide bed should be adequate. The last stride in the gas cleaning is the water scrubber. In the water are a large portion of the contaminations evacuated, similar to particles, tars, antacids, and incandescent light. The wastewater originating from this framework needs facilitate treatment before it can be arranged.

4.2-HIGH TEMPERATURE GAS CLEANING

The gas is in the high temperature gas cleaning is initially gone through a hot gas channel. This channel is built from either metal or a fired material. At that point the gas is gone through the tar wafer, so as to diminish the measure of tars in the gas. This tar saltine is really a pressed bed containing an impetus, similar to dolomite or a metal based catalyst. The tar saltine works at 800 C, and a tar transformation of 99% can be accomplished. Next, the gas is gone thro1ugh a reformer, so as to lessen the sum light hydrocarbons in the gas; this will likewise expand the sum hydrogen in the gas. At that point the salts are caught up in a safeguard, which contains a purported soluble base getter. For this situation

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bauxite is picked as antacid getter, since it can be recovered. At that point the gas is cooled by adding some steam to the gas before it enters the sulphur evacuation unit. Likewise, for this situation the sulphur evacuation happens in a stuffed bed of zinc oxide.

5-GAS PROCESSING

Gas Processing have three steps. They are

1. Reforming
2. Water gas shift
3. Pressure Swing Adsorption

5.1. Reforming

Reforming is a process where hydrocarbon like methane is converted into carbon dioxide and hydrogen in presence of steam.

CH_4 + 2H20 ∅ CO + $4H_2$……………………. ……. Eqn.1

5.2. Water gas shift

6-EXERGY ANALYSIS

Exergy Analysis is performed using conservation of both mass and energy with the second law of energy to check energy losses and to enhance the performance of the system. The exergetic efficiency is defined as ratio between exergy output and exergy input. For reference state temperature was about 298k and pressure was 1 atm. We will be analysing the exergetic efficiency of Hydrogen gas at two points. One, when gas is leaving the HT shift reactor and one at LT shift reactor. For this we will be using the formula.

The carbon monoxide gas which is produced in the gasifier can also be used to produce hydrogen gas. This is done by using waster gas shift method.

CO+ H_2O ∅ CO_2 + H_2……………………………… Eqn.2

5.3. Pressure Swing Adsorption

This procedure depends on the standard of sub-atomic sieving. The gas is nourished to an arrangement of stuffed beds at hoisted weights (3.1–3.4 MPa) and at encompassing gum based temperature (20–30 C). The beds contain zeolites or enacted carbon, which assimilate every one of the polluting influences in the hydrogen. The procedure fills in as takes after: gas is encouraged to the initially bed until it is practically immersed. At that point the gas is sustained to a moment bed, amid that time the initially bed is depressurized. Amid the depressurization the consumed polluting influences desorb, after desorption the bed is cleansed. In the time the initially bed is recovered the second bed gets to be distinctly immersed, after which the gas bolster is changed back to the initially bed.

Exergy Efficiency = ??? ?
(((((((((((...................Eqn.3
?????? ???? ???????

Where,

ExH_2 = Exergy of hydrogen.

Ex Biomass = Exergy of biomass.
Ex Steam= Exergy of steam.

Table 1: Temperature and pressure of the main process stream

Process Stream	Reference (a) Temperature (K)	Pressure (Bar)	Total exergy
Biomass (feedstock)	298	1	5427.835
Steam	773	50	217838.63
Hydrogen (HT shift reactor)	623	30	274156.984
Hydrogen (LT shift reactor)	473	25	273876.268

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Table 2: Chemical exergy, specific heat capacity, molar mass, enthalpy, entropy

Reference (c) & (f)

Substances	**Chemical exergy (kj/kmol)**	**Specific heat capacity Kj/kg. k**	**Molar mass Kg/kmol**	**Enthalpy Ho**	**Entropy So**
H2	236100	14.307	2.016	0	130.68
Steam	9500	1.8273	18.015	-241820	188.83

7-CALCULATION

Total Exergy = Physical Exergy + Chemical exergy …………………………………… Eqn.4
Physical Exergy = (h-ho) –To(S-So)………………………………………………..Eqn.5
Change in Enthalpy = m*s*t…………………………………………………………. Eqn.6
Change in Entropy = Cp log e (T/T1)…………………………………………………Eqn.7

Where,

m = mass
s = specific heat capacity
t = change in temperature

For HT shift reactor

ExH2 = 274156.984
ExBiomass = 5427.835
Ex Steam = 217838.63

Exergy Efficiency =

274156.984

((((((((
5427.835 + 217838.63

= 1.23% ……………..Eqn.8

For LT shift reactor

ExH2 = 273876.268
ExBiomass = 5427.835
Ex Steam = 217838.63

Exergy Efficiency = 273876.268/5427.835+217838.63

= 1.22%..........................Eqn.9

8-CONCLUSION

Biomass generally consist of manure, dungs, waste from household. Since, it is known as biomass is a renewable source of energy and production of hydrogen from it, is a good approach to sustainable development. In this paper exergetic analysis were done of the production of hydrogen form biomass. Two cases were studied i.e. High temperature shift reactor and low temperature shift reactor. After carrying out the analysis it is found to be that HT shift reactor gives the better efficiency of the production of hydrogen gas. From my knowledge, high temperature in the reactor giver better yield of hydrogen, however studies have proved that using fossil fuels instead of biomass will give even better efficiency for the production of hydrogen but it is not recommended as fossil fuels are non-renewable source of energy and is also an expensive process.

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