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Generation of Hydrogen from Biomass through Thermo-Chemical Fluidized Bed Gasification

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Abstract

Hydrogen is considered as a novel fuel for the twenty first century, mainly due to its environmentally pollution free benign character. Production of hydrogen from renewable sources like biomass has several advantages compared to that of fossil fuels. A number of processes are being developed throughout the world for efficient and economic conversion of biomass to hydrogen.
The work undertaken by CMERI includes the development of a fluidized bed system for gasification of biomass in a thermo chemical reactor using steam as an oxidizing agent instead of air. Steam is used for increase of hydrogen percentage in the product gas with a heating value in the range of 11.0 to 13.5 MJ/Nm3. Initially rice husk has been taken as the suitable fuel. The system is also suitable for other biomasses like wood-dust, sawdust, bagasse etc.

Keywords: Hydrogen, biomass, CMERI, oxidizing agent, rice husk etc.

“1. Introduction.”

Biomass is a general term for living materials – plants, animals, fungi, bacteria. Since biomass can be re-grown, it is a potentially renewable resource.One of the most appealing things about biomass energy is that it doesn't contribute to the enhanced green house effect, provided that the biomass is harvested sustainably. An important application of biomass conversion could be generation of hydrogen, which is considered as a green fuel and suitable for application in fuel cell and other devices as fuel[1]. Thermo-chemical gasification of biomass has been identified as a possible process of hydrogen production[2].

Gasification is a thermal process that converts solid fuel into a fuel gas mixture of medium to low heating value. The gasification reaction being endothermic requires heat. Heat addition is done directly by partial oxidation of the fuel or indirectly using some means of high rate indirect heat transfer. As reported in the literature, fluidized bed thermal gasification of biomass is an effective route that results in almost 100% conversion of the various biomass fuels, e.g., wood, energy crops, agro-residues, etc., to energy offering economical and environmental benefits[3].The products of solid biomass fuel through thermo-chemical conversion can be classified into three different categories: gases, tars and char.

A number of types of gasifiers have been developed to meet the different needs. The development of the fluidized bed gasifier (FBG) for small particles has made great progress for biomass gasification[4].The circulating fluidized bed gasifier (CFBG) has certain good features - fast fluidization which enhances the heat and mass transfer to speed up the gasification process and the circulation of the char with increased residence time decreases the char loss[5].

CFB conversion of biomass are expected to be characterized by i) acceptance of a wide variety of biomass feeds; ii) flexible scale-up from small to large capacity up to 10– 50MW thermal input iii) high heat and mass transfer intensity iv) high thermal capacity per unit of sectional area iii) relatively easy scale-up v) easy control of temperature to keep the temperature profile ideal vi) flexibility with regard to feed rate and its composition[6]. If these expectations could be met, CFB conversion of biomass for fuel gas will be a promising alternative to bio-energy industry.

The fast-fluidized bed depends on the following conditions - (1) smaller size particles (2) high operating gas velocity (3) continuous solid circulation [7]. Small particles provide huge gas-solid contact surface, minimizing the transfer resistance among the particles. High gas velocity with solids circulation means that there is an absence of bubbles forming a dilute continuum of discrete particles with solids clusters in it.The continual forming and dispersing of the solid clusters promote the contact of gas and solid and enhance heat and mass transfer. Continuous solid circulation maintains the uniform bed density and solids profile in the radial cross section. Consequently, the fast-fluidized bed provides a high reaction rate for combustion and enough residence time of solids to complete the reactions.The main two reactions are

Gasification Reaction: $C + H_2O = CO + H_2$ $\Delta H = +122$ KJ/mol

Combustion Reaction: $C + O_2 = CO_2$ $\Delta H = -400$ KJ/mol

Biomass gasification has been studied through thermo-chemical process in a laboratory scale circulating fluidized bed gasifier.A cold model Perspex make circulating fluidized bed system comprising of a 50 mm diameter fast bed and a 100 mm diameter bubbling fluidized bed has been designed and developed. The fast bed and the bubbling fluidized bed signify combustor and gasifier respectively. The recirculating rate of inert sand particle has been found out both theoretically and experimentally. Recirculating rate for biomass and sand mixture varies from 170 kg/hr to 43 kg/hr for mixture ratio of 0 to 1.5.A 10.0 kg per hour biomass cutting and sizing machine has been designed and developed. A two-stage water-cooled screw feeder for biomass has been designed and developed.A 1.0 kg per hour electrically heated laboratory scale 60 mm dia fluidized bed biomass gasifier has been designed and developed. Rice husk has been gasified with steam as fluidizing media. The furnace has been operated in the temperature range of 650^0 to 750^0 C. The fuel gas generated contains 48.6 % H_2 and 20.2 % CO.

Then a 5-kg/hr circulating fluidized bed biomass gasifier has been designed and developed. The experimental unit is shown in fig.

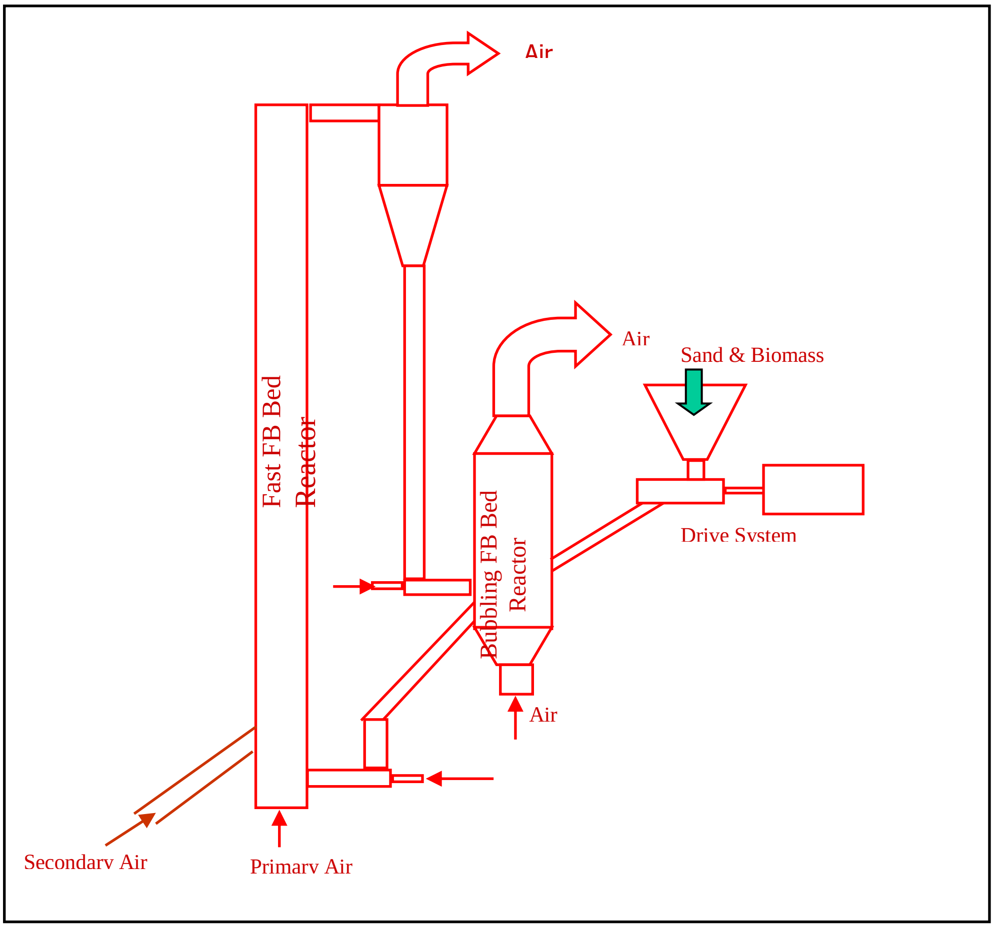


Fig.5.Circulating fluidized bed gasifier

"Fig.1. Close view of circulating fb biomass gasifier with feeding system."

"2.Methods."

Feed materials

Rice husk was taken as the raw material since it is one of the important biomass resources in India. The proximate and ultimate analyses of rice husk are

Proximate Analysis

	Weight %
VM	55.54
FC	14.99
Ash	19.52
Moisture	9.95
Total	100.00

Ultimate Analysis Dry basis

	Weight %
C	38.43
H	2.97
N	0.49
O	36.36
S	0.07
Ash	21.68
Total	100.00

The steam, the gasification agent, had been used as the fluidizing media as it prevented the dilution of product gases with nitrogen and also increased the hydrogen content in the product gas[8].

Experimental set up and procedure

The circulating fluidized bed gasification system comprises of two fluidized bed reactors – one is the bubbling bed gasifier and the other is fast bed combustor. The inside diameter of gasifier is 100 mm and the height is 1.2 m. The combustor is made of a 52 mm inside diameter pipe with a height of 6.0 m. The hot sand particles are carried away with the entraint flue gas and get separated in a cyclone before it is directed to a gasifier wherein this hot sand serves as a heat source for the pyrolysis and gasification reaction of the biomass material. The gasifier and combustor reactors are interconnected by a 25 mm diameter pipe. Relatively less hot sand mixed with char particles goes back into the combustor after gasification reaction.

The gasifier system operates at low inlet steam velocities (0.2 – 0.4 m/s) for the production of fuel grade gas from solid biomass fuels and the gasifier temperature is maintained between 650^0C and 800^0C. The gasifier system is integrated to a fast bed combustor in which the char gets combusted in presence of air to heat the inert sand particles. There are two sources of air in the combustor. The primary air contributes to ensure bubbling fluidization of char and sand mixture and the secondary air is mainly responsible for carrying the hot sand particle to the top of vessel after complete char combustion. The air velocities are in the range of 3–5 m/s and the temperature of the combustor is controlled within 900^0C. Experiments were carried out with a constant biomass feed rate 5.0 kg per hour.

In fluidized bed systems wherein sand is used as a heat transfer medium from a combustor to a gasifier, it is necessary to minimize or eliminate the leakage of oxygen containing gases from the combustor into the gasifier. The heat carrying inert sand material is transported from the combustor to the gasifier and back while preventing the entry of air (oxygen) into the gasifier. Thus, the product gas from the gasifier has a medium range heating value.Contamination of the gasifier with air (oxygen) results in the undesirable formation of carbon dioxide and water from the CO and H_2 end products of the gasification reaction, thus lowering the efficiency of gasification.

The control of gasifier temperature is very important to avoid problems resulting from the agglomeration of the ash, sand and char mixture, and subsequent blockage of flow through the system. At the high operating temperatures of gasifier system, sometimes a portion of the agglomeration of ash is the result of the partial melting of the ash constituents. Thus it is clearly be desirable to develop a method of reducing or eliminating the agglomeration of the ash, sand and char mixture.The product gas from the gasifier is made dust-free and cleaned by passing it through a gas cleaning column before it is put into the gas chromatograph for online analysis.

“3.Gas analysis results and discussion.”

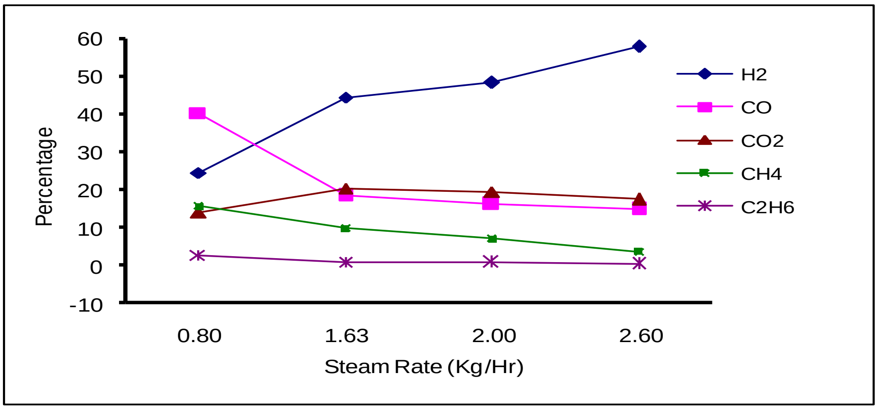
The circulating FB system has been run at different operating conditions varying the input parameters and the product gas mixtures have been analyzed online by a Gas Chromatograph. The results are discussed bellow

Steam Rate

In these tests, steam rates were varied in the range 0.8 – 2.6 kg per hour maintaining all other conditions constant. The product gas analyses are presented in the Fig.1 . With the increase of steam flow rate, the hydrogen concentration showed a gradual increased trend while those of CO and CH_4 have been decreased. Biomass feed rate was fixed at 1.0 kg per hour. The increased trend of hydrogen concentration may be explained by that there were more steam reforming reactions of CO, CH_4 and C_2H_4 taking place because of increased steam quantity.The product gas composition based on process parameters reported in literature are different due to diversity of gasifiers, biomass, moisture and steam-biomass ratios used. The variation in gas composition is due to the different operating conditions of the fluidized bed gasifier. Thus, for good result, a perfect combination of all parameters, especially the reactor bed temperature and the steam flow rate, should be maintained properly.

“Table 1. Showing the product gas composition with steam flow rate.”

Sl. No.	Steam Rate	H_2	CO	CO_2	CH_4	C_2H_6
1	0.80	24.479	40.400	14.100	15.56	2.690
2	1.63	44.478	18.392	20.464	9.849	0.862
3	2.00	48.392	16.215	19.549	7.035	0.625
4	2.60	58.028	14.920	17.356	3.656	0.351



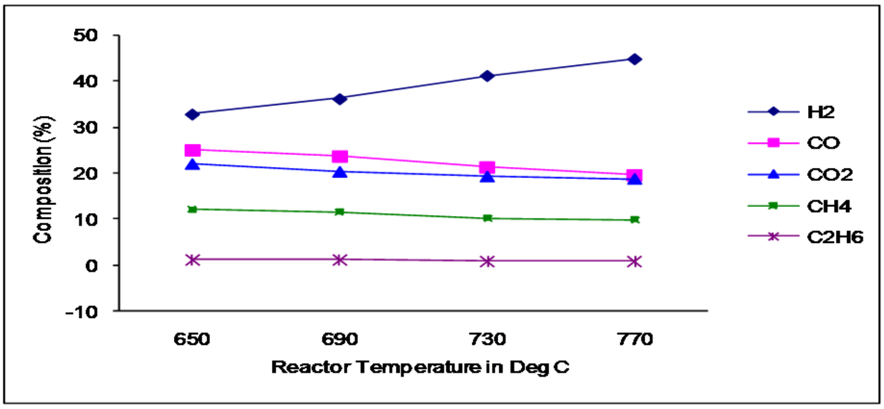
“Fig.1. Steam rate vs gas composition (reactor temperature 750^0 C).”

Reactor Temperature

The reactor temperatures were varied keeping other parameters unchanged and the product gases were analyzed individually. Fig. 2 shows the composition of the product gas at different reactor temperatures. It is observed that H_2 and CO concentrations increased with rise in temperature and the concentrations of CH_4 and CO_2 showed an opposite trend.

"Table 2.Showing the product gas composition with reactor temperature."

Sl. No.	Reactor Temperature	H_2	CO	CO_2	CH_4	C_2H_6
1	650	32.842	25.127	22.045	12.156	1.202
2	690	36.165	23.762	20.305	11.620	1.057
3	730	41.214	21.432	19.251	10.225	0.892
4	770	44.850	19.600	18.720	9.908	0.805



"Fig.2. Reactor temperature vs gas composition – steam rate is maintained at 1.32 Kg/hr."

"4.Conclusion."

A 5.0 kg per hour laboratory scale circulating fluidized bed biomass gasifier comprising of a 50 mm dia fast bed combustor and a 100 mm dia bubbling fluidized bed gasifier has been designed and developed. The product gas generated has been analyzed by a gas chromatograph. The gas mixture contains 58.0 % H_2 and 14.9 % CO with a calorific value of 12.5 MJ/Nm^3.

A water-scrubbing unit for cleaning of product gas has been designed and developed.

A gas flaring system has been designed and developed to burn gas generated and avoid CO pollution in atmosphere.

"5.Future Work."

The work was carried out in a lab scale unit that has certain limitations on several aspects e.g., continuous feeding of loosely bonded agricultural residues, instrumentation, measurement facility etc. Non availability of smaller size components/ equipments led to some problems. Larger pilot plant may circumvent some difficulties.

With this background, CMERI wishes to propose a project as future work. The development of a 200 KW twin fluidized bed pilot plant test facility for generating medium calorific value synthetic fuel gas through thermo-chemical gasification of biomass may be taken up as a future work. Rice husk, sugarcane bagasse and cotton waste will be primarily considered as feedstock. Emphasis may be given to develop gasification technology for agro wastes or residues. Gas cleaning including tar conversion and removal of undesirable components produced along with the product gas by using agricultural residues as feedstock will be investigated. This synthetic fuel gas after thorough cleaning may be utilized in combustion engine or for fuel cell applications.

"6.Acknowledgement"

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“7.References”

[1] Hydrogen from biomass Kaushik Nath and Debabrata Das Current Science, vol 85 no 3, 10 Aug, 2003

[2] An experimental study on biomass air–steam gasification in a fluidized bed P.M. Lv , Z.H. Xiong, J. Chang, C.Z. Wu, Y. Chen, J.X. Zhu Bioresource Technology 95(2004) 95-101

[3] A consideration of the economic effciency of hydrogen production from biomass Waichi Iwasaki International Journal of hydrogen Energy, 28(2003), 939-944

[4] Development of catalysts suitable for hydrogen or syn-gas production from biomass gasification S. Rapagna, H. Provendier, C. Petit, A. Kiennemann, P.U. Foscolo Biomass and Bioenergy 22 (2002) 377-388

[5] Biomass conversion into fuel gas using circulating fluidised bed technology: the concept improvement and modelling discussion G. Chen, J. Andries, H. Spliethoff Renewable Energy 28(2003) 985-994

[6] Design and operation of a CFB gasification and power generation system for rice husk XiuLi Yin, Chuang Zhi Wu, Shun Peng Zheng, Yong Chen Biomas and Bioenergy 23 (2002) 181 – 187

[7] Biomass pyrolysis/gasification for product gas production: the overall investigation of parametric effects G. Chen, J. Andries, Z. Luo, H. Splietho Solar Energy 76 (2004) 345 - 349

[8] Hydrogen rich gas from biomass steam gasification H.Hofbauer, R.Rauch, P.Foscolo, D.Matera Report No JOR3CT970196, The E/uropian Commission, March 2001