Reason - A Technical Journal
ISSN 2277–1654
Vol - XII ● 2013

RICE HUSK AS A LOCAL RESOURCE IN DEVELOPING ENERGY SECURITY

Krishna Hazra

Mechanical Engineering Department, Future Institute of Engineering & Management
Kolkata 700150, West Bengal, Email: hazra_krishna@yahoo.in

Paper received on: January 15, 2014, accepted after revision on: March 2, 2014.

Abstract : To enhance the income and to reduce the poverty one has to look at the village level industries. One of the major village level industries is food-processing industry. In the eastern part of India rice mills may be categorized under major industries. These rice mills, due to scarcity of grid electricity, had shifted to diesel based captive power generation and, of late mostly shifted to biomass gasifier based power generation systems using their own byproduct, the rice husk, to replace diesel and thus saving both cost and diesel and, at the same time going renewable.

Keywords: Energy security, synthetic fuel, gasifier, pyrolysis, updraft fixed-bed gasifier, producer gas, CO_2 emission.

1. INTRODUCTION

Fuel wood is the major energy resource in West Bengal. Here agriculture is the backbone of the economy. Sometimes agricultural wastes replace fuel wood. The device used for conversion of the fuel wood into thermal energy has very low efficiency, in the range of 8 to 12%. So, initiatives have been taken to install energy efficient devices for conservation of the firewood and agricultural waste. In west Bengal, there are nearly 785 rice mills with production capacity varying from 2 ton to 180 tons per day during the peak season. The peak season extends up to six months a year. After that the rice mills face a lean period. With the enhancement of high variety of agricultural products, multi-crop cultivation is introduced in this region. The industries also demand more energy for enhancing productivity. Rice mills consume both thermal and electrical power for rice processing as the people in this region consume par-boiled rice. Thermal energy is used for steam generation and electrical energy is required to run machineries in the mill. In the old days par-boiled paddies were dried outside in the sunshine. Due to some problems and to enhance the productivity, artificial driers have also emerged in the rice mills. As a result, energy consumption pattern in the rice mill have changed; the demand for the conventional energy in the rice mill have increased. The electricity supplied by the state electricity authority and the quality of the supply is poor. Thus the mill cannot work with full efficiency. In order to enhance the efficiencies, most of the rice mills put a captive diesel generator set to supply quality power as well as to meet the demand during the load-shedding period. The captive power was profitable when the diesel price was Rs. 10.00 a litre. Presently, the price of the diesel is more than 5 times the previous. Thus captive generation now is not economical at all. To conserve the diesel fuel, steps have been taken to generate synthetic fuel using the local resources. Rice mills produce husk as by-product and the husk has consumption only in firing the boiler for steam generation and for running the drier. A major portion of the husk remains unutilized and it becomes waste. Introduction of gasifier technology to gasify rice husk into synthetic fuel may be a solution to generate power using local resources. The synthetic fuel from the gasification of rice husk is a mixture of CO, H_2 and CH_4 as the main combustibles. The gasifier generates a synthetic fuel and engine which starts with diesel, reduces diesel consumption during the engine's operation. Thus gasification satisfies the purpose of providing local energy security because, firstly, it is a locally available resource and secondly, it conserves diesel for generating the power which is ultimately required for achieving the Energy Security. Many reports are available regarding the power generation using rice husk gasification [1-2]. The Gasification process and its application are discussed below in detail.

2. GASIFICATION PROCESS

The gasification is the thermo-chemical conversion of solid hydrocarbon fuel into energy-rich gaseous fuel. The gasification of solid fuel takes place in air-sealed closed chamber under a little suction or pressure relative to the ambient pressure. The thermo-chemical reaction is quite a complex phenomenon. Where this process takes place is known as a gasifier. Normally the gasification occurs through four distinct zones viz. Drying, Pyrolysis, Oxidation and Reduction. Splitting of the gasifier into strictly separate zones is not realistic, but nevertheless conceptually essential. The various steps for gasification are given below:

Rice husk gasifier is a kind of device, which can generate fuel gas from the gasification of biomass. It is basically a two-part system - upper and middle and the fuel gas is extracted either from the downward direction or the upward direction. Extraction of gas from the down ward direction is known as down draft system and extraction of the gas from the upward direction is called the updraft system.

The gasification process takes place at a high temperature condition in presence of small amount of oxygen. Temperature has a big role to play, particularly in rice husk gasification. At lower temperature rice husk shield the carbon and so good quality gas containing carbon monoxide and hydrogen can not generate. At higher temperature the silicate formation appears which shields the carbon from reaction with the oxygen [3-6]. Thus, an appreciable temperature is essential to have a good reaction with carbon and oxygen. Tars and particulates must be filtered or flashed out from the gas to produce a clean and cool gas to make it suitable for various kinds of applications mainly for internal combustion engines and gas turbine applications but for direct heating applications through immediate combustion, cooling and cleaning of this gas is not required, which makes an updraft gasifier highly suitable for such purposes.

Various companies and various manufacturing units have their own designs to generate good quality gas. Biomass is fed in the upper chamber and it is passed through the lower chamber with the impact of external vibration. The vibration initiates the peristalsis process in the gasifier to pass the biomass chips to the combustion zone.

2.1 Principle of Gasification

The various processes in a gasifier that take place during gasification are as given bellow. In actual case the feeding material faces four temperature-driven processes. These are:

(i) Drying
(ii) Pyrolysis
(iii) Oxidation
(iv) Reduction

Table 1: Temperature at Various Stages of Gasification

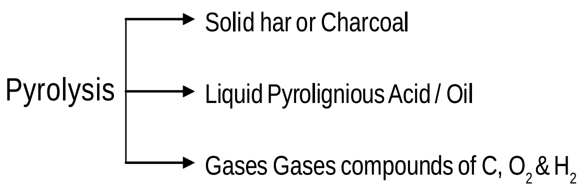
Stages of Gasification	Drying	Pyrolysis	Oxidation	Reduction
Temperature (^{0}C)	140-150	150-700	700-2000	800-1100

Drying

In this zone 5 to 10% of the moisture content in the biomass fuel is reduced. The water content from the biomass gets removed and converted into steam at the temperature above 100^0 C. The biomass does not experience any kind of decomposition during drying process.

Pyrolysis

Thermal decomposition of biomass fuel takes place in presence of low amount of air in the Pyrolysis zone. In the pyrolysis zone three kinds of products are generally produced; these are solid, liquid, and gases. The chemical composition and the operating condition generally influence the ratio of the products. The heating value of gas produced during the pyrolysis process is low.



There will always be a low temperature zone in the gasifier where pyrolysis will take place and generate considerable hydrocarbon.

Oxidation

In the oxidation zone air reacts with biomass. Oxygen and also water vapor take part in this reaction. Inert gases like nitrogen (N_2) are generally considered non-reactive with fuel. Oxidation takes place at a temperature of around 700-2000^{0}C. Heterogeneous reactions take place between O_2 of the air and solid carbonized fuel from the pyrolysis zone and produces CO_2; the reaction is exothermic one, like, the very simple reaction as follows:

$$C + O_2 = CO_2 + 394 \text{ MJ/kg-mol}$$

(N.B.: Exothermic reaction is represented by the plus sign and endothermic reaction by the minus sign.)

In this reaction 12.01 kg of C is completely combusted with 22.39 m^3 of O_2 supplied by air to yield 22.26 m^3 CO_2 and 394 MJ of heat. Hydrogen available in the fuel reacts with O_2 available in the air to produce steam following the reaction as follows:

$$H_2 + ½ O_2 = H_2O + 242 \text{ MJ/kg-mol}$$

Reduction

In this zone a number of high temperature chemical reactions, both exothermic and endothermic, take place in absence of air in the reduction zone. The main reactions are given below:

$CO_2 + C = 2CO – 173$ MJ/kg-mol
——— Boudouard Reaction

$C + H_2O = CO + H_2 - 131$ MJ/kg-mol
——— Water gas reaction

$CO_2 + H_2 = CO + H_2O + 41$ MJ/kg-mol
——— Water Shift Reaction

$C + 2H_2 = CH_4 + 75$ MJ/kg-mol
——— Methane Production Reaction

Main reaction shows that heat is required during the reduction process. Hence, the temperature of the gas goes down during this stage. Thus, after all the thermo chemical reactions in the reduction zone the obtained gas is a mixture of combustible gases namely, carbon monoxide, hydrogen and methane in small quantity along with incombustible gases like nitrogen and carbon dioxide in small quantity if left out or reproduced in the reduction zone. The left out unconverted carbon from the reduction zone is known as char. The intended use of the gas and the characteristic of the gasifier and associated equipment i. e. size, texture, moisture content determine the design and operating characteristics of the gasifier and associated equipment. Typically, a gasifier supplier will specify the characteristic of the biomass required for satisfactory performance. Solid hydrocarbon based materials, like coal, mineral oil cake, biomass etc. can be used as the feed for gasifier. After complicated thermo-chemical reactions the said materials are converted into gaseous ones, which, in turn, can be used for heat production as well as electricity generation.

The overall efficiency of the system is higher than the conventional combustion system and is more environmental friendly. Typical gas has energy values in the range 4-5 MJ m^{-3} [3] with an average input energy content of biomass of 17.5MJkg^{-1} [7]. Obtained gas, usually called Producer Gas is a mixture of gases, as reported earlier, having volumetric composition by percentage as CO- 17-22 %, CO_2- 9-15%, H_2- 12-20%, N_2- 50-54%, and CH_4- 2-3% [8]. The outlet temperature of the gas remains between 200–300°C and contains large amount of tar and particulates. Cooling and filtering of Producer Gas is generally done by passing the gas through a water scrubber and a dry packed bed filter. The water comes out after filtering is highly acidic in nature. After cooling and cleaning the gas is used for direct heating applications or as a fuel for dual fuel engines for power generation [9-11]. In case of power generation operating in full load condition the producer gas from rice husk gasification reduces the diesel consumption by around 70% [12].

2.2 Gasifier Types

At the present moment, two basic gasifier designs are in use: (i) Updraft, and (ii) Down draft fixed bed gasifier.

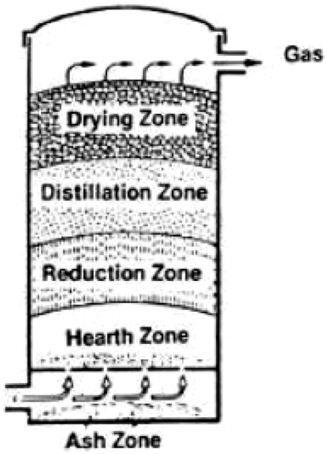


Fig 1: Schematic Diagram of an Updraft Fixed-Bed

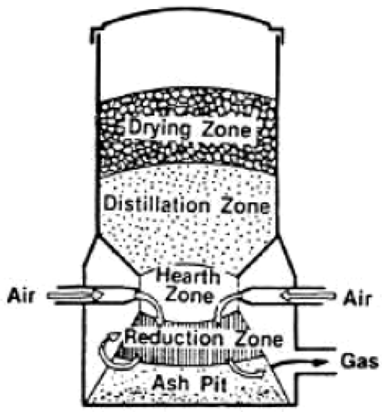


Fig 2: Schematic Diagram of a Downdraft Fixed-Bed Gasifier

The schematic diagram of an updraft fixed-bed gasifier is shown in Fig.1. In this design air is injected at the bottom of the gasifier and biomass feed stock is allowed to enter from the top and moves down under the action of gravity as it is gasified. The entering biomass undergoes drying followed by partial gasification and finally combustion of the ungasified solid fraction. Updraft gasifiers have high energy efficiencies due to the efficient counter current heat exchange between the rising gases and descending biomass. However, the product gases from updraft gasifiers have unacceptably high concentration of tars and particulates. Tars and particulates must be filtered or flashed out from the gas to produce the clean and cool gas that is required for many applications, such as generating electricity or shaft power with an engine. Removal of tars and particulates reduces the overall efficiency, since they constitute an important fraction of the energy content of the gasified biomass. Thus, in practical operations, the use of updraft gasifiers has been limited to direct heating applications where no gas cleaning and cooling is required.

The schematic diagram of a down draft fixed-bed gasifier is as shown in Fig.2. Normally the downdraft fixed bed gasifiers produce significantly less tar. In this kind of gasifier, the producer gas is drawn out from below, from the reduction zone. The entire initial tar produced is broken down into lighter gases without sacrificing their energy content. This leaves the reactor at a higher temperature than that of an updraft gasifier. With tar production minimized, gas cooling and cleaning can be done with acceptably small energy losses.

3. APPLICATIONS OF GASIFIER IN INDUSTRIAL GRADE POWER GENERATION AND ITS ECONOMICS

It has been already mentioned that gasification of biomass produces synthetic fuel or fuel gas during the gasification process. The fuel gas has two major applications in two distinct modes: (i) Thermal mode, and (ii) Electrical mode.

The calorific value of this gas is around 1000 kcal per m^3 (4.18MJ per m^3) and is known as low B.T.U. gas. This gas can be burnt in a burner to generate thermal energy or this gas is fed to engine with diesel to increase its calorific value. As a result, application of thermal and electrical modes becomes successful. Many industries are using this gasification technology for Industrial application. In case of thermal mode, generating hot air is one of the major applications. In such applications, hot air is used for drying purpose in food processing and chemical industries. The food processing and chemical industries generate hot air for their own processing. A producer of a branded product of mosquito repellent is producing process hot air using gasifier. Though Mosquito repellent is manufactured by mechanical stamping of a chemical paste. The chemical paste requires drying at a temperature of 80-90^{0}C. The hot air at that temperature is blown over the stamped paste and drying occurs. The industry was earlier using light diesel oil or furnace oil to run their furnaces to produce the hot air for this drying process. Injection of light diesel or furnace oil in the burner some times creates a problem due to clogging by these hydrocarbons. As a result, workers sometimes face the problem of non-uniform temperature generation of hot air, which affects the product and the processing. However introduction of gasifier generated synthetic fuel does not pose the same problem when it is burnt. As a result low B.T.U. gas from gasifier becomes a choice for an able substitute to the industry.

In the power generation sector this technology puts a major impact to the industry economics. The industrial application of gasifier is shown in the photograph (Fig. 3). During the field studies it has been observed that a 250 kWe gasifier consumed 250 × 1.2 kg of rice husk and immature paddy per hour. Immature paddy has a big impact in power generation [13].

Fig 3: A typical 250 kwe gasifier unit of a rice mill

It acts as a flasking media to perfect gasification of rice husk. After the gasification the gas is fed to a diesel generator having capacity 250 kVA. This diesel generator in normal condition consumes 54 litres of diesel per hour. Coupling of Gasifier to the diesel engine at present is consuming only 12 litres diesel per hour. Thus there is net saving 42 liters per hour. If it conserves 42 litres of diesel per hour and the engine runs for 15 hour a day then net diesel conserved per day is 600 litres. If the engine runs 300 days in a year net diesel saving is 300 × 600 = 1,80,000 litres of diesel per year which conserve not only conventional fuel but also emission of CO_2. In this respect cost of power production from the gasification technology can be presented by a general formula.

General Formula For Calculation

Cost of unit power = [Interest on capital investment + (Cost of biomass per hour + Cost of diesel per hour) x Hours of operation + Overhead cost] / No of units generated

3.1. Electricity Production Cost Using Producer Gas–Diesel Dual-Fuel Generator

Capacity: 100 kWe System

Capital Investment (including equipment & Installation)		**INR 20,00,000**
Biomass (Wood) Consumption		**120 kg/hr**
Diesel Consumption (70% / 80% replacement)		**6.45/4.35 lit/hr**
Operating Worker		**2 persons**
Maintenance/Spare Parts (Assuming 1% of Capital Cost/yr)		**INR 20,000**
A. Fuel Cost per unit (kWh) of electricity		
i) a. Diesel Cost at 80% diesel replacement	@ INR 58.00/litre	INR 2.52
i) b. Diesel Cost at 70% diesel replacement	@ INR 58.00/litre	INR 3.74
ii) Fuel Wood	@ INR 4.00/kg	INR 4.80
iii) Husk	@ INR 2.00/kg	INR 2.40
iv) Husk + Immature Paddy	@ INR 1.50/kg	INR 1.80

B. Operation and Maintenance Cost (with 50% CUF) and 15 hrs of operation per day		
i) Operating Charges	@ INR 10,000/month	INR 0.45
ii) Maintenance	@ INR 20,000/yr.	INR 0.045
C. Cost of Electricity Generation at 80% diesel replacement		
i) Using fuel Wood & Diesel		**INR 7.815/kWh**
ii) Using Husk & Diesel		**INR 5.415/kWh**
iii) Using Husk + Immature Paddy & Diesel:		**INR 4.505/kWh**

3.2 Calculations on the Potential for Power Generation in West Bengal

a. Raw Paddy Production	200×10^5 Tons / Yr.
b. Availability of Husk (Approximately 22% of Raw Paddy)	44×10^5 Tons / Yr.
c. Availability of Immature Paddy (IP) (Approximately 3% of Raw Paddy)	6×10^5 Tons / Yr.
d. Total availability of Husk and IP	50×10^5 Tons / Yr.
e. Other use of Husk	10% use as Poultry Feed & Fodder
f. Surplus Husk & IP	45.6×10^5 Tons / Yr.
g. Required Biomass for Power Production	1.26 kg per kW
h. Potential for Power Production	3600 MWh

3.3. Calculation on Diesel Saving and Reduction in CO_2 Emission

a. No. of Rice Mills in West Bengal:	Approximately 785
b. Capacity for Captive Diesel Generator:	Approximately 75kVA
c. Average Diesel Consumption:	12 liter per hour
d. Diesel Saving:	8.4 liter per hour
e. Diesel Saving by 785 Rice Mills:	6594 liters per hour
f. Operation Period of Mills (Assuming 120 days for 15 hours a day and 180 days for 7 hours a day)	2860 hours
g. Total Diesel Saving (i.e. 6594 x 2860)	1,88,58,840 Liters
h. CO_2 emission per liter of Diesel:	2.65 kg
i. Total CO_2 emission reduction:	49,976 Tons

It has been observed that incorporation of the gasifier saves diesel in power generation mode. The gasifier has two impacts in two distinct criteria

(i) Socio Economic

(ii) Environment

As mentioned above, the agricultural activities generated the avenues for income generation in the local and regional level. As a result many people are involved in rice production, rice collection, rice transportation and rice processing. These complete an economic cycle like resource generation, resource distribution and resource re-circulation and this is an achievement in village level economy. During these circulations process there are possibilities of loses in each step of the above processes. The losses occur in terms of the environmental cost, which accounts at the present moment in terms of Green House Gas (GHG) production. Energy sector is a major emitter of Green House Gases in the atmosphere; Gasifier integration reduces the emission level to a great extent. A model calculation reveals that if all the rice mills in West Bengal implement gasifier technology the total savings in diesel consumption as well as CO_2 emission will be as shown in section 3.3.

4. CONCLUSIONS

The above studies indicate the use of the local resources in developing Energy Security. Gasification is a viable technology for producing industrial grade power or grid quality power. It has major application both in small scale as well as large-scale industries. Application of Gasifier in thermal mode is restricted to the medium temperature range and in electrical mode it may require backup fuel to enhance the charge calorific value in the cylinder of the IC engine. Thus in power generation mode duel fuel engine shows this successful application. Nevertheless the gasifier is still suffering from the same problems like gas cooling and cleaning mechanism. Biomass contains organic chemical or volatile matter like phenolic compounds, which are very corrosive in nature. The acidic characteristic reduces the viscosity of the lubricating oil of the diesel engine. This is a major problem for coupling gasifier to the diesel generator in its application in power generation mode.

REFERENCES

[1] Jain, A., Rao, T.R., Sambi, S.S. and Grover, P.D., Biomass and Bioenergy, Vol.7, pp.285-289, 1995.

[2] Natarajan, E., Ohman, M., Gabra, M., Nordin, A., Liliedahl, T. and Rao, A.N., Biomass and Bioenergy, Vol.15, pp.163-179, 1998.

[3] Natarajan, E., Nordin, A. and Rao, A.N., Biomass and Bioenergy, Vol.14(5/6), pp.533–46, 1998.

[4] Bingyan, X. and Zongnan, L.A., Study of Fluidized Bed Gasification Rice Hulls, Advances in Solar Energy Technology, Biennial Congress, Hamburg, Germany, pp.2312–2316, 1987.

[5] Xu, B.Y., Huang, W.C., Flanigan, V.J. and Sitton, O.C., Design and Operation of a 6 in Fluidized Bed Gasifier for Rice Hulls, Symposium on Energy from Biomass and Waste IX, Organized by IGT, Chicago, USA, pp.595–613, 1985.

[6] Xiu, L.Y., Chuang, Z.W., Shun, P.Z. and Yong, C., Biomass and Bioenergy, Vol.23, pp.181-187, 2002.

[7] Ciferno, J.P. and Marano, J.J., Benchmarking Biomass Gasification Technologies for Fuels, Chemicals and Hydrogen Production, Department of

Energy, National Energy Technology Laboratory, US, June 2002.

[8] Stassen, H.E.M. and Knoef, H.A.M., Small Gasification Systems, Biomass Technology Group, BV, Netherlands.

[9] Kendall, A., McDonald, A. and Williams, A., The Power of Biomass, Chemistry and Industry, Vol.9, pp.342-345, 1997.

[10] Mills G.A., Status and future opportunities for conversion of synthesis gas to liquid fuels, Fuel, Vol.73, pp.1243-1279, 1994.

[11] Parkinson, G. and Fouhy, K., Gasification: New Life for an Old Technology, Chemical Engineering, Vol.103, pp.37-43, 1996.

[12] Ghosh, B., Dey, S. and Pal, J., Possibilities and Potential for Industrial Grade Power from Bio-Mass Gasification, Proceedings of the International Seminar on Decentralised Energy: Options & Management, Kolkata, India, pp.116-122, 22-24 February, 2002.

[13] Ghosh B., Energy Securities Using Local Resources: An Indian Experience, EU Conference on Bioenergy, Vienna, Austria, 2004.