Rice Husk: A Sustainable Biomass for Rural Electrification

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Abstract: The aim of the study is to meet the socio-economic development of rural areas through electricity by developing small industry, supplying power to irrigation pumps, generating employment and improving the quality of life of rural people.

India is one of the biggest rice producers in the world, not surprisingly, also produces vast amounts of rice husk. The rice husk is the outermost layer of the paddy grain that is separated from the rice grains during the milling process. Around 20 % of paddy weight is husk and rice production in Asia produces about 770 million tons of husks annually which are equivalent to 250 million tons of oil equivalent according to various scientific reports. A small (10 kW capacity) biomass gasifier based power plants can be managed by village community, using biomass generated from agricultural waste for decentralized distributed electricity generation.

In the present study a comprehensive review of techniques used for utilizing rick husk as biomass in a gasifier, experimental investigation, characterization, merits, and demerits and challenged are discussed.

Keywords: rice husk, biomass, gasification, electricity

1. INTRODUCTION

Indian agriculture sector constitutes 62% of the people. So, the quality of life of rural people depends on growth in agriculture sector. This sector will grow if agricultural inputs will available at affordable cost. Among various inputs in agriculture, energy or power plays a vital role in determining total agricultural inputs. Due to high agricultural inputs, agriculture becomes non profitable despite high yield. Here we focus to reduce agricultural input cost and more particularly energy inputs in agriculture.

The demand for direct energy input in agriculture in the year 2016 is projected to be 33.33 million tons of oil equivalents (MTOE) if agricultural GDP grows at 3 per cent and 41.49 MTOE if agricultural GDP grows at 4 percent [1]. India generates over 500 million tones of biomass material every year through its agricultural and agro-forestry operations and it is estimated at around 175 MTOE [2]. A portion of these materials is used for fodder and fuel in the rural economy. However, studies have indicated that at least 150-200 million tones of this biomass material does not find much productive use, and can be made available for alternative uses at an economical cost. These materials include a variety of husks and straws. Biomass fuels and residues can be converted to energy via thermo-chemical processes like pyrolysis or gasification and reduction to a gaseous fuel called producer gas. This gas is used as fuel for internal combustion engine and electricity can be generated through shaft power application when engine is coupled to a generator.

2. BIOMASS UTILIZATION TECHNIQUES

2.1. Direct combustion

Combustion is the most traditional and common process of converting biomass into usable energy. It is a thermo-chemical conversion process utilizing the major feedstock such as agricultural residue. (Eq. 1)

$$\text{Biomass}+O_2 \longrightarrow \text{Heat}+CO_2+H_2O+\text{Ash} \qquad (1)$$

2.2. Biomass gasification

Chemical process of gasification means the thermal decomposition of hydrocarbons from biomass in a reducing atmosphere at about 850 °C. A biomass gasifier can operate under atmospheric pressure or elevated pressure. The resulting gas product contains combustible gases – hydrogen (H_2) and carbon monoxide (CO) as the main constituents; by-products are liquids and tars, charcoal and mineral matter (ash or slag). The net product of air gasification can be found by summing up the partial reactions, as in Eq. 2.

$$\text{Biomass } (C_6H_{10}O_5) + O_2 \rightarrow C_XH_Y + C_LH_MO_N + CO + H_2 + \text{Heat} \qquad (2)$$

2.3 Anaerobic digestion – Biogas

Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH_4) and carbon dioxide (CO_2), known as biogas. This complex biochemical reaction carried out in a number of steps by several types of microorganisms that require little or no oxygen to live. In this process, principally approximately 65% CH_4 and about 30% CO_2 is produced. The amount of biogas produced varies with the amount of organic waste fed to the digester and temperature influences the rate of decomposition. Several different types of bacteria work in stages together, to break down complex organic wastes, resulting in the production of biogas as in Eq. 3.

$$\text{Biomass} \xrightarrow{\text{Anaerobic digestion}} CH_4+CO_2+H_2S+N_2+H_2+O_2 \qquad (3)$$

2.4 Ethanol production

Starch content of biomass feed stocks can be converted by fermentation process into alcohol. Fermentation is the biochemical process that converts sugars into alcohol in the presence of air (Eq. 4).

$$\text{Biomass} \xrightarrow{\text{Hydrolysis}} \text{Sugar} \xrightarrow{\text{Fermentation}} \text{Ethanol} + CO_2 \quad (4)$$

1. Among all the alternatives of technology used, gasification is the best suitable alternative in view of the following points [3]:
2. Gasification offers high flexibility in terms of various biomass materials as feedstock.
3. Gasification has thermo-chemical conversion efficiencies in the range of 70-90 %, which is highest among various alternative.
4. Gasification output capacity, especially in the high output ranges, is controlled only by availability of adequate feed materials rather than technical consideration.
5. The area requirement for gasification equipment is lowest per unit output of energy in the form of heat and/or electricity.

The gasification equipment has high turn down ratios comparable to biogas.

3. MATERIAL AND METHODS

3.1. Characteristic of rice husk

The rice husk is the outermost layer of the paddy grain that is separated from the rice grains during the milling process. Around 20 % of paddy weight is husk and it is largely considered a waste product that often burned or dumped on landfills.

The higher the energy content and bulk density of fuel, the similar is the gasifier volume since for one charge one can get power for longer time [4, 5]. The rice husks generated from agricultural activity have the fine sizes, generally high ash content and low bulk densities. The bulk density is determined as the mass per unit volume in a container which accounts for void spaces in between particles. The characteristics of the agricultural wastes on dry basis are shown in table 1.

Table 1: Typical characteristic of rice husk

Typical Size [mm]	Ash content [%]	Bulk density [kg/m^3]
8 - 10	20	100 - 130

These residues cannot be directly gasified in a packed bed downdraft gasifier for several reasons – (a) the material movement by gravity will be hampered by low bulk density and wall friction, (b) tunneling of air can occur by the creation of a hole in the bed somewhat randomly affecting the gas quality, (c) operation of the gasifier at high throughputs particularly in a classical closed top design leads to high temperature near air nozzles because of the influence of high velocity air flow from the air nozzles on the char and this can lead to ash softening and clinker formation and it also reduces the effective area for flow through the reactor, further deteriorating the performance of the gasifier. Certain gasification technologies have used open top packed bed gasifier for bio-residues (mostly rice husk) allowing shorter residence time and extraction of the char at a higher rate. In this case the reactor acts more as a pyrolyser than gasifier as the carbon conversion will be low. It is the understanding and experience on such systems over years that focused the attention on the use of the light and fine residues by converting them into solid form.

3.2. Briquetting

The process of briquetting involves subjecting the biomass to high pressure and temperature which helps in release of lignin from the biomass. This lignin acts as a natural binder and the loose biomass matter gets tightly packed and takes the size and shape of the die. The briquettes ensuing from the briquetting machine will be hot and upon cooling will become hard with individual briquette density varying from 900 to 1100 kg/m^3. The bulk density of rice husk before and after briquetting was found to be 100-130 kg/m^3 and 400-450 kg/m^3 respectively [6]. Briquetting can be done either by screw type machine or ram type machine. Bulk densities of

3.3. Biomass gasifiers

In a biomass gasifier, the biomass is burnt in limited supply of oxygen. This results the formation of a combustible mixture containing CO (15-30%), H_2 (10-20%) and CH_4 (2-4%) besides the non-combustible components of CO_2 (5-15%), H_2O (6-8%) and the rest N_2. The process involves drying of biomass followed by pyrolysis, i.e., breaking up of biomass into char and volatile matter [7]. The reactions between the combustion products and the char at high temperature lead to the final gaseous mixture called producer gas. The final products also include some unburned volatile matter in vapour form, which can condense when the gas cools to form a sticky substance called tar. When gas is burnt in a burner for thermal application, tar does not pose much problem. However, for use in an IC engine, the gas needs to be cleaned of tar more thoroughly. The tar content must be less than 50 mg/m^3, which needs an elaborate cooling and cleaning system. The tar content in the producer gas depends strongly on the design of the gasifier. Low tar content requires high temperatures, around 1200 °C in the combustion zone of the gasifier. It also needs high residence time of the gas in the high temperature region.

Most of the gasifiers in the field are of two types: (i) updraught type where the gas flow is upwards through the biomass and char bed, while the biomass moves down. (ii) downdraught type where the gas also flows downwards, in co-current with biomass as shown in Fig.1. The downdraught type of design gives much less tar in the final gas as compared to the updraught design. However, an updraught gasifier is much simpler to build and operate but produces more tar. Hence, updraught gasifiers are more commonly used for thermal applications.

3.4. Ash fusion

The agro residues are characterized with medium to high ash content as shown in table 2. This ash additionally has alkali salts that lower the ash fusion temperature. The in-organic content in biomass is not fixed and can vary from region to region and practices adopted for cultivation. A reference data taken from [8] is shown in table 2.

Table 2: Ash deformation and fusion temperature of rice husk

Ash Deformation temperature [°C]	Ash Fusion temperature [°C]
1430 – 1500	1650

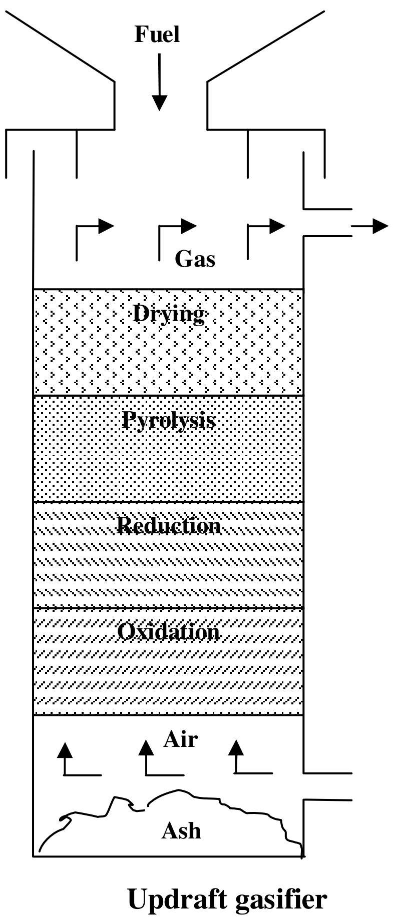

Fig.1. Updraft and downdraft gasifiers.

4. REVIEW OF PAST EXPERIMENTS

A large number of researches were carried out with biomass as a replacement of internal combustion (IC) engine fuel by researchers from various parts of the world. A summary of these experimental results is given below.

Vyarawalla *et al* [9] have designed and developed a 9 kW capacity biomass-based gasifier engine system for laboratory experiments by using saw dust and toor stalks as biomass. They could achieve the diesel saving up to 75% by compression ignition type engines by producer gas from gasifier. Krishna & Kumar [10] worked on coffee husk as biomass for gasification to analyse the performance of diesel engine on dual fuel mode. The maximum diesel replacement of 31% only was reported. Jorapur & Rajvanshi [11] suggested the commercial scale (1080 MJ/h) development of a low density biomass gasification system for thermal application. The gasifier can handle fuels like sugarcane leaves, bajra stalks, sweet sorghum stalks and bagasse, etc. Tripathi *et al* [12] studied biomass residues of arhar stalk, maize stalk, maize cobs, cotton stalk, mustard stalk, jute and mesta sticks, rice husk and groundnut shells have been assessed. It is reported that more than eight million tonnes of these residues were produced in the year with a primary energy potential of about 1200 Peta Joules. He reported that these agricultural residues may be profitably used as feedstock in biomass gasification and briquetting plants. The usage of producer gas, a lower calorific gas as a reciprocating engine fuel at a high compression ratio (17:1) is technically feasible (Sridhar *et al* [13]).

5. CONCLUSION

Biomass gasification offers the most attractive alternative energy system for rural electrification. India being a major agricultural country rice husk gasifiers produce a change in the energy scenario of the country. By biomass gasification process the rice husk burn to produce producer gas, which can be used as a fuel in any stationary engine, which would then be coupled with a generator to generate electricity.

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