JOURNAL OF ADVANCEMENT IN
ENGINEERING AND TECHNOLOGY
Journal homepage: www.scienceq.org/JAET.php
ISSN: 2348-2931
V6I4.01
Research Article Open Access

Energy Potential of Rice Straw in India and Assessment of Various Technologies Suitable for Its Efficient Energy Utilization

Shailesh Bobade[1], Pravin Mane[2], Kishor Vaidya[3]
[1,2] Walchand College of Engineering, Sangli 416415, Maharashtra, India.
[3] B&H Division Thermax Ltd. Pimpri Chinchwad, Pune, Maharashtra, India.
*Corresponding author: Shailesh Bobade, E-mail: sbobade007@gmail.com
Received: May 25, 2018, Accepted: July 02, 2018, Published: July 02, 2018.

ABSTRACT
At present achieving fuel economy and reducing emissions are the two main targets set by the automotive industries. The homogeneous charge compression ignition (HCCI) is an advanced combustion technology that is cleaner and more proficient than alternate kinds of combustion. Regardless of the way that the fuel conversion efficiency and NO$x$emission of HCCI engine are more prominent in examination with conventional engines, HCCI combustion has a few fundamental issues, for example, concession combustion phase control, controlled auto-ignition, operating range, preparation of homogeneous charge, cold start and emissions of unburned hydro carbon (UHC), and carbon monoxide (CO) should be defeat for effective process of HCCI engine. Most of the researcher worked out on preparation of homogeneous fuel-air mixture. In this paper, review to give an overview on earlier work did on the external mixture formation methods and which are implemented and offered in the present years. The various methods of combustion phase control by HCCI combustion are also discussed and various Numerical investigations methods on HCCI engine are also presented.

Keywords: *Bio Fuels, HCCI, stratified charge compression ignition (SCCI), low temperature combustion (LTC), Emissions, Simulation*

INTRODUCTION
In countries like India where agriculture is the main occupation for most of the people, there is common practice of strawopen burning in fields after crop harvesting. This open burning results in emissions to air that have a hazardous effect on air quality and human health. The majority of land in India is used for farming and a wide range of crops are cultivated in the different regions. The major annual crop production in India is rice (104 Mt) followed by wheat (93 Mt). In 2013, the world rice production was 477 Mt, wherein, China was the first producer with 144 Mt and India, second with 104 Mt (21% of total world rice production) [1]. Consequently, rice straw alone is produced in large quantities and contributes to 23% of the total agricultural crop residue (IARI, 2012). In most states of India, farmers grow three crops in a year and the mode of harvesting is changing from manual to mechanical, which leaves the straw standing in the fields. To clear the field for the next crop farmers, apply the illegal practice of burning of straw leading to harmful effects on the environment and leads to the loss of nutrients such as N, P, K, and S [2]. Open burning of these residues could be avoided if incentives are provided to the farmers via residue utilization which could yield monetary benefits. Straw as agricultural waste biomass could be a source of alternative energy to substitute fossil energy for reducing greenhouse gas emissions as well as avoid the local pollution problems from open burning. Therefore, to avoid these hazardous effects of burning and to take advantage of the huge energy potential of straw, the utilization of straw for various other activities should be promoted.

Rice husk is used currently for power generation in few countries of Asia. In the similar way the use of rice straw residue is a major breakthrough than using rice. The first step is to estimate the quantity of rice straw produced using Straw-to-Grain Ratio (SGR) or Residue-to-Product Ratio (RPR). SGR of 0.75 derived from other study [2] is used which in general could be applied to the country India which is under study. Rice cultivation is a very distributed activity, therefore field-based residue, i.e. rice straw availability would also vary both in spatial and temporal distributions; and practices in crop harvesting will be useful while estimating the energy potential of rice straw.

1. MATERIALS AND METHODS:
An average of past few years' data was analyzed in order to minimize variation of rice straw availability annually, and similarly for representing distribution in different areas. The most recent year's data are presented for seasonal availability. The following sub-sections would detail the methodology followed to estimate the quantity of rice straw produced, identifying the possible energy potential.

2.1. Estimation of rice straw produced which can be utilized for energy production:
The amount of rice straw produced could be derived using the following equation:

$$Q_{RS} = 1.5 \times P_R \times SGR \qquad (1)$$

Where Q_{RS} is quantity of rice straw
P_R is average rice produced annually
SGR is Straw to Grain Ratio
The amount of rice straw produced in India could be estimated by using Eq. (1) as it needs multiplying rice production data by a factor of 1.5 to translate in terms of rough rice [1] and equate with other country data analysis. Rice production in India for the year 2016-2017 is 109 MMT [5].
Q_{RS} is 122.625 MMT

2.2. Quantity of rice straw available for energy production:
The North and North-Western parts, especially Punjab and Haryana, are dominated by rice wheat crop rotation. As wheat Straw is preferred as fodder for cattle, farmers generally do notuse rice straw and prefer open-field burning. However, in Southern part of India, rice straw is used as a fodder, and to a smaller extent used in paper factories or as building materials in the construction of house or other applications.

As per the data received from the National Biomass Resource Assessment (NBRA) Programme, the availability and use of rice straw varies widely across India. The data from research indicate that 28% of rice straw is used for domestic uses. Among the domestic uses, only about 5–60% isused as domestic fuel and this number varies from state to state considerably. About 49%of the straw is used for other activities, which include fodder and thatching applications. Only 23% of the total rice straw is currently surplus, of this, the state of Punjab and Haryana alone constitute 48%and could be used for energy applications [2], as given in table 1. The intensive rice wheat croprotation in these states does not allow retaining the crop residues in the field for an extended duration, hence it is often open-burnt.

Thus considering 23 % surplus rice straw of available Q_{RS} which gives Q_{ERS} rice straw available for energy production

$Q_{ERS} = 0.23 \times 122.62$
$= 28.2$ MMT

2.3. Energy Potential of available rice straw :

To find energy potential first we need LHV of rice straw which is given by

LHV = 34.8C + 93.9H + 10.5S + 6.3N - 10.8O - 2.5 W (2)

where in c – carbon, h – hydrogen, s – sulphur, n – nitrogen, o – oxygen, and w – moisture are indicated in volume percentage [2]

Using equation 2 and Ultimate analysis Table 2:

LHV is calculated to be 16.4 MJ/kg

Assuming Plant efficiency 25 % energy potential of rice straw can be calculated

E_{RS} = (Amount of straw burnt ∗ LHV of straw ∗ Conversion efficiency)/3600 MWh

$= 32.16 * 10^6$MWh

2.4. Assessment of technologies for heat and power production from rice straw:

2.4.1. Grate fired boiler

The grate firing technology is old, well proven, relatively cheap and used wide spread in different countries and using a great variety of fuels, also difficult fuels like wheat straw. A grate fired boiler is very robust when it comes to variation in fuel size, moisture content, ash composition etc [3]. Grate-firing is one of the main competing technologies in biomass combustion for heat and power production, because it can fire a wide range of fuels of varying moisture content, and requires less fuel preparation and handling.

The grate, which is at the bottom of the combustion chamber in a grate-fired boiler, has two main functions: lengthwise transport of the fuel, and distribution of the primary air entering from beneath the grate. The grates are mainly classified into stationary slopinggrates, travelling grates, reciprocating grates, and vibrating grates, the major characteristics of which are summarized as below

Sloping Grate:

The grate does not move. The fuel burns as it slides down the slope under gravity. The degree of sloping is an important characteristic of this kind of boiler.

Disadvantages: (1) difficult control of the combustion process; (2) risk of avalanching of the fuel.

Travelling Grate:

The fuel is fed on one side of the grate and is burned when the grate transports it to the ashpit. It is a moving grate that allows continuous automatic ash discharge and consists of cast iron or ductile iron grate bars attached to chains that are driven by a slow moving sprocket drive system. Compared to stationary sloping grate, it has improved control and better carbon burnout efficiency (due to the small layer of fuel on the grate). The main advantage of this grate is its ability to follow load swings and the automatic ash discharge that permits continuous operation on biomass fuels.

Reciprocating Grate:

The grate tumbles and transports fuel by reciprocating (forward or reverse) movements of the grate rods as combustion proceeds. Finally, the solids are transported to the ash pit at the end of the grate. Carbon burnout is further improved due to better mixing.

Vibrating Grate:

The vibrating grate allows intermittent, automatic ash discharge. The grate consists of castir on grate bars or bare tube panels attached to a frame that vibrates on intermittent basis, controlled by an adjustable timer. The grate has a kind of shaking movement that spreads the fuel evenly. This type of grate has less moving parts than other moveable grates (and thus lower maintenance and higher reliability). Carbon burnout efficiency is also further improved. There are two major types that have been used for biomass fuels, one water cooled and the other air cooled. A key advantage of the vibrating grate is the low number of parts that are highly stressed, moving or in sliding contact. This results in reduced maintenance requirements. The vibration is intermittent and several vibration sequences (vibration frequency, duration, and time span between vibrating periods) are used [6]

2.4.2. Fluidized Bed Combustion:

In concept, fluidized beds burn fuel in an air-suspended mass (or bed) of particles. By controlling bed temperature and using reagents such as limestone as bed material, emissions of nitrogen oxides (NOx) and sulfur dioxide (SO2) can be controlled. Compared to the grate firing technology, it can obtain slightly higher efficiencies and lower operational and maintenance expenses. FB boilers are mainly used in timber and paper industry using woody residuals as fuel. FBC boilers can be built a little bigger than grate firing boilers; from very small up to approximately 100 MW. FBC boilers require certain moisture content in the fuel to keep the temperature at an acceptable level. The FBC boiler is therefore not recommendable for a dry fuel like straw. In addition the alkali content in straw will cause problem in a FBC boiler [6]

2.4.3. Cigar Burning Technology:

In this technology whole straw bales are fed to the boiler as it is and are burned from one side similar to the burning of cigar. Shredding of bales is not required. Air tight sealing of bale feeding system is used to avoid back fire. Efficiency of this technology is less compared to grate firing. Only small power plants of capacity up to 3 MW are found to be running on this technology. Also no power plant using rice straw bales as fuel is found using this technology. This technology is not yet fully developed to be used for rice straw as fuel [4].

2.4.4. Gasification:

Gasification is a thermochemical conversion process in which biomass is converted into a high energy gas called syngas which can be combusted further to provide energy. The quality and calorific value of the syngas depends on the characteristics of the biomass used, as well as the gasifying agent, method of conversion, and operating conditions. The highest calorific value syngas is usually produced using hydrogen as the gasifying agent, although air is probably the most common agent used. The fixed bed gasifier is the traditional technology, and includes updraft, downdraft, and cross-bed systems. The difference within each is where and in which direction the feed and fuel gas are introduced. Typically, fixed bed gasifiers produce lower calorific value syngas with high tar content.

In terms of using rice straw as the biomass fuel for gasification, there are still many problems to be overcome. Rice straw has a high alkalinity content which creates many problems with slagging in boilers. The potassium and chloride content of rice straw contribute especially to the accumulation of slag. A possible solution to this problem is to leave the rice straw in the fields for a longer period of time to allow for natural leaching of alkaline. However, farmers are likely to be unwilling to do this as it reduces field turnover time and may prove uneconomic. Another problem with rice straw is the high silica content of rice straw, which results in high ash content. This reduces the energy efficiency of the technology as the ash must be removed and disposed of. There are limited commercial situations where rice straw is the main fuel used for gasification. For a commercial plant, efficiency may be lower as there is more energy demands associated with a system of this scale.

Although the technology for biomass gasification has been well proven and is already in use in many facilities, there are only a few cases where rice straw has been the biomass used. For the most part, rice straw for gasification is being used only on a demonstration level, rather than full implementation in industry. As mentioned above, many problems regarding the quality of rice straw need to be overcome before this method of conversion can be economically attractive enough to be used on a large scale.

2.4.5. Pyrolysis:

Pyrolysis is a type of thermochemical conversion technology that involves direct liquefaction using heat and pressure in the absence of oxygen to produce oil, syngas, and char. While combustion and gasification are efficient on a large scale, there are high costs to collect, transport, handle, and store crop residues. Although pyrolysis is slightly less efficient than gasification, by using pyrolysis, biomass can be converted to bio-oil that can be transported easily to act as a fuel for combustion or gasification. In order to be as efficient as possible, pyrolysis requires small (<10 mm) and dry (<10wt% moisture) biomass feedstock, which can typically produce bio-oil yields. However, to utilize pyrolysis, the biomass waste must be less than 6 mm, although 1-2 mm is best. Also, the biomass must have less than 10% moisture content in order to guarantee high heat transfer rate [7].

3. RESULTS AND DISCUSSIONS:

As the annual rice production in India is enormous the residue rice straw after harvesting is also huge. Only considering surplus rice straw which is burned in open field and neglecting the amount of rice straw which is used for thatching, fodder, domestic fuel energy potential is calculated. This energy potential after evaluating and taking into account of plant efficiency comes $32.16 * 10^6$MWh which is enormous for considering its use as fuel in boiler.

Further different energy utilization technologies are studied from various literature which could be used to extract this energy from rice straw in an efficient way. Among these technologies fluidized bed combustion is suitable for most of the biomass but in case of rice straw which has high ash contain and in that high alkali percentage which leads to bed material agglomeration. So this technologies cannot be considered for rice straw unless any additives are added in it to reduce agglomeration. Gasification and pyrolysis are yet to be commercialized for rice straw as fuel. This technology is still in research phase and tested on pilot plants of very small capacity. Many problems regarding the quality of rice straw need to be overcome before this technology can be economically attractive enough to be used on a large scale.

Grate firing technology for rice straw is most suitable technology among these. Reciprocating grate and vibrating grate prove to be more efficient for rice straw combustion in boiler as it contains high ash and has low LHV value. Hence among these technologies reciprocating grate and vibrating grate can be selected for energy utilization from rice straw.

4. Acknowledgment

The author wish to thank Mr. Prakash Soman (Head, Innovation and Automation, B&H Division, Thermax Ltd. Pune) and team for the valuable inputs during this research.

Table. 1 Current uses of rice straw in India

Domestic	28%	Domestic Fuel
Others	49%	Fodder and thatching applications
Surplus	23%	

Table 2 Ultimate Analysis of rice straw [1]

Element	C	H	O	N	S	Cl	Ash
%	45.2 %	6.5 %	47.5 %	0.8 %	0.009 %	0 %	13.7 %

REFERENCES

1. Shveta Soam, Pal Borjesson, Pankaj K. Sharma, Ravi P. Gupta, Deepak K. Tuli, Ravindra Kumar, “Life cycle assessment of rice straw utilization practices in India”, Bioresource Technology 2016, Elsevier
2. Butchaiah Gadde, Christoph Menke, Reiner Wassmann, “Rice straw as a renewable energy source in India, Thailand, and the Philippines: Overall potential and limitations forenergy contribution and greenhouse gas mitigation”, Biomass and Bioenergy 33 (2009) 1532–1546, Elsevier.
3. Chungen Yin et al, “Grate-firing of Biomass for Heat and Power Production”, Progress in Energy and Combustion Science 34 (2008) 725– 754, Elsevier
4. B.S. Repic, D.V. Dakic, A.M. Eric, D.M. Djurovic , A.D. Marinkovic, S.Dj. Nemoda, “Investigation of the Cigar Burner Combustion System for Baled Biomass”, Biomass and Bioenergy, 58(2013) 10-19, Elsevier.
5. www.agricoop.gov.in/sites/default/files/Rice%20profile%20July-%202017.pdf
6. Steam: Its Generation and Use, The Babcock & Wilcox Company, 42nd Edition
7. Hyungseok Nam, Sergio C. Capareda, NanjappaAshwath, JinjutaKongkasawan “Experimental investigation of pyrolysis of rice straw using bench-scale auger, batch and fluidized bed reactors”, Energy 93 (2015) 2384-2394, Elsevier.

Citation: Shailesh Bobade et al. (2018). Energy Potential of Rice Straw in India and Assessment of Various Technologies Suitable for Its Efficient Energy Utilization, J. of Advancement in Engineering and Technology, V6I4.01. DOI: 10.5281/zenodo.1303056