Use of Agri-waste for the Development of Sustainable Energy Resources

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Abstract - Present energy resources are largely dependent on fossil fuels. These are non-renewable energy resources and polluting our environment by rapid release of combustion products. These declining energy resources and severe environmental constraints compel us to sharply focus our attention on the need for additional amounts of clean energy resources. Among the energy resources that can substitute fossil fuels, biomass fuels appear as an option with the highest general worldwide potential. Partial combustion of biomass in a gasifier generates producer gas, which can be used for heating purposes and as supplementary or sole fuel in internal combustion engines. An analysis has been made in this paper to find the potential of rice-straw and wheat-straw as the feedstock for gasifier. The performance of the gasifier engine system is analysed by running an engine (dual fuel C.I. engine) for various flow ratios of producer gas and at different load conditions. The system is experimentally optimized to get maximum diesel savings in the dual fuel mode operation while using the biomass fuels. The performance of the dual fuel engine is compared with that of diesel engine at different load conditions.

Key Words: Agri-Waste, Biomass, Energy, Sustainable Energy Resources.

1. INTRODUCTION

Energy is the most basic requirement for economic growth and development of a country. Before the industrial revolution people were essentially dependent on manual and animal labour but as the revolution took place, the new electrical age started by the invention or introduction of electrical machines along with commercial availability of electrical power. All this led to an increase of energy required by leaps and bounds. Energy has been the life-blood for continual progress of human civilization. Also the per capita energy consumption of a country is an index of the standard of living or prosperity of the people of that country. As India enters the new millennium with population of one billion, the necessity of producing enough energy and applying engineering for greater infrastructure development has been increased. It compels us to look ahead and gear ourselves to clear the backlog of development and meet future challenges. India will continue to experience an energy supply short fall through the forecast period. This gap has been exacerbated since 1985, when the country became a net importer of coal. Also, India is unable to raise its oil production. The requirement of energy, its production and shortage during past years has been depicted in table I.

Table I
Energy Planning and shortage during some 5 Years Plans [1]

5 Years Plan	Demand (MW)	Installed Capacity (MW)	Shortage (MW)
6th (1980-85)	52,000	47,000	5000
7th (1985-90)	75,000	65,000	10,000
8th (1990-92,92-97)	1,05,000	85,000	20,000
9th (1997-2002)	1,32,000	1,05,045	26,955
10th (2002-2007)	1,46,000	1,32,329	13,671

In spite of increasing demand of energy and depletion of available conventional resources from earth, environment pollution is another major reason, which compels us towards the non-conventional energy sources. There are drastic changes in the composition and behavior of the atmosphere due to the rapid release of polluting combustion products from fossil fuels. A significant amount of the carbon dioxide emissions from the energy sector is related to the use of fossil fuels for electricity generation. As the demand for electricity is growing rapidly, emission of carbon dioxide and other pollutants from this sector can be expected to increase unless other alternatives are made available. The energy sources that can substitute fossil fuels are solar, wind, ocean & biomass. Apart from being pollution free, these are inexhaustible and are freely available everywhere. Energy scenario is changing rapidly and dramatically in favour of non-conventional energy resources.

Biomass is a renewable energy resource derived from agricultural wastes, e.g. straw, rice husk, bagasse, groundnut shells etc., and a variety of wastes arising from cattle dung, municipal solid waste, sewage and canteen wastes. India produces about 500 million tons of agricultural residues comprising of mainly rice husks, paddy straw, sugarcane waste, wheat residues and cotton stalks. It is estimated that about a half of this or 300 million tons of residues are not being utilized and are disposed of by burning them in the open fields and creating environmental hazards [2]. Every year Govt. of India issues the stringent laws to avoid the burning of these residue wastes in open field but those laws or warnings are not taken care of. These solid biomass fuels can be effectively harnessed by converting them into a gaseous combustible fuel termed as "Producer gas" in suitable designed reactors (Biomass Gasifier). The process used for this purpose is called gasification. Gasification is the process of converting solid/liquid fuel into gaseous fuel. It involves the devolatilization and conversion of biomass in an atmosphere of air to produce a medium or low calorific value gas. Gasification is a form of pyrolysis, carried out at high temperatures. The ratio of oxygen to biomass is typically around 0.3. The resulting gas, known as producer gas, is a mixture of carbon monoxide, hydrogen and methane, together with carbon dioxide and nitrogen. G. Sridhar et al. [3] discussed the usage of producer gas, a lower calorific gas as a reciprocating engine fuel at a high compression ratio (17:1). From that study it is established beyond doubt that the operating engines using producer gas in SI mode at higher compression ratio is technically feasible. Jorapur and Rajvanshi [4] reported the commercial scale (1080 MJ/hr) development of a low-density biomass gasification system for thermal application.

The gasifier can handle fuels like sugarcane leaves, bajra stalks, sweet sorghum stalks & bagasse etc. From the results it is demonstrated that low-density biomass gasifier running on sugarcane leaves or bagasse can be successfully used along with existing oil fired furnaces/boilers in metallurgical & other industries. Krishna and Ajit Kumar [5] used coffee husk as biomass for gasification and analyzed the performance of diesel engine on dual fuel mode and replaced the 31% diesel consumption by gas. It has been seen in literature that most of the work has been done on biomass gasification of wood chips only. But a lot of other agricultural residues are also available. In this paper *rice straw* and *wheat straw* has been used as biomass fuel as their disposal is considered as a challenging environmental problem while burning in open fields. The important properties of *rice straw* and *wheat straw* are compared with that of wood as shown in Table II.

Table II
Characterization of fuels

Biomass	Ash %	C %	H %	N %	O %	S %	Calorific Value (MJ/kg)
Wheat straw	8.90	43.20	5.0	0.61	39.40	0.11	17.4
Rice straw	10.70	42.30	5.60	0.90	40.50	0.02	11.7
Wood chips	3.20	48.60	5.56	0.60	41.46	0.03	17.4

2. EXPERIMENT METHODOLOGY

The *biomass gasifier* used for experimental purpose is shown in fig. I (Appendix) and its main components have been identified. The biomass is fed through the feed door and is stored in the hopper. Limited and controlled amount of air for partial combustion enters through two air nozzles. The gas outlet is connected with the engine via venturi scrubber, separator box cum fine filter and check filter with an air control valve to facilitate running of the engine in dual-fuel mode. The valves are provided in the passage of gas and airflow to control the gas. A single cylinder naturally aspirated direct injection four-stroke diesel engine (see table III for specifications) coupled with generator is used for the power generation. The performance tests are carried out in diesel mode and dual fuel mode at different load conditions. The dual fuel mode of operation is carried out by supplying the gas to the combustion chamber of the engine through inlet manifold. The gas control valve is opened gradually to feed gas into the engine. The engine governor control knob is slowly closed to decrease the amount of diesel supplied. Diesel fuel consumption is checked by using a burette. With the rotation (opening) of gas valve the amount of gas entering into the engine varies. The optimum adjustment of gas and diesel supply can be made.

Table III Specification of engine used

Make	Kirloskar
Type	Single Cylinder, Four Stroke Air Cooled Diesel Engine.
Rated Power	5 kW
Speed	1500 rpm
Loading device	Electrical generator

3. RESULTS AND DISCUSSIONS

Fig. II, III and IV explains the specific diesel consumption in dual fuel mode operation using different bio fuels (wheat straw and rice straw) at different producer gas flow ratios (two, four & six revolutions) at different loads. From each figure it is clear that as the producer gas is increased there is a decrease in diesel consumption. Hence higher diesel substitution in dual fuel mode of operation is achieved by opening the producer gas valve fully so that higher amount of producer gas flow will replace the higher amount of diesel.

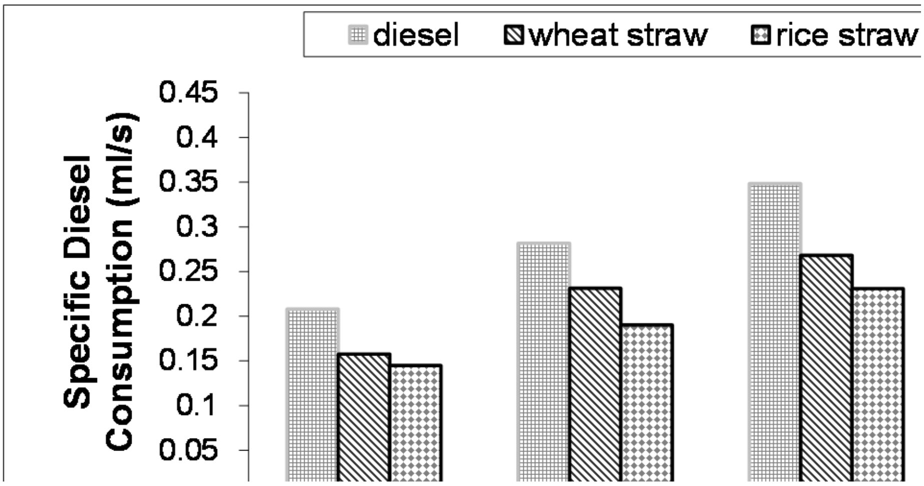

Fig. II: Specific fuel consumption at two revolution opening

When rice straw is used for making producer gas the diesel substitution varies from 30% to 46.08%. The maximum diesel substitution is obtained at full opening of gas flow valve. The results of using wheat straw for the producer gas generation in gasifier show that the minimum diesel substitution in dual fuel mode is 24.17% while maximum diesel replacement is of the order of 36.17%.

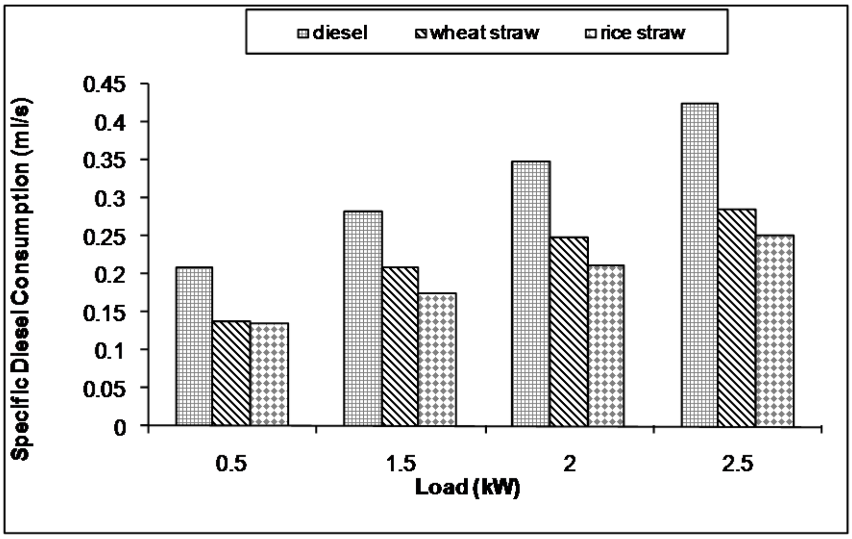

Fig. III: Specific fuel consumption at four revolution opening

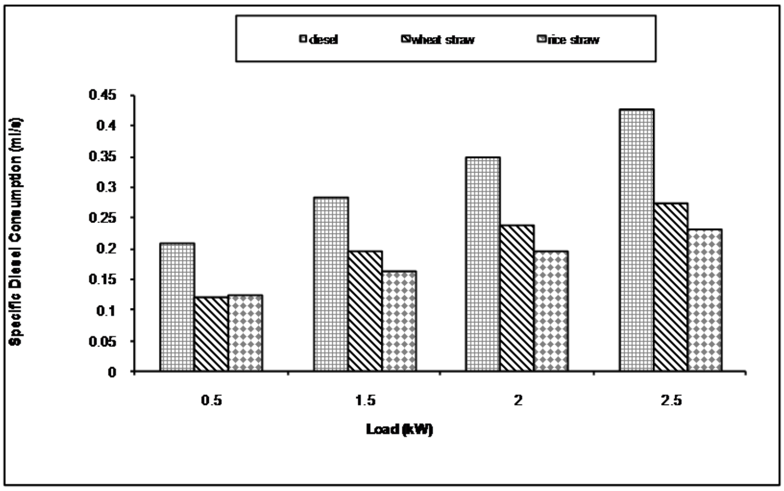

Fig. IV: Specific fuel consumption at six revolution opening

Nitrogen is present in the rice straw and wheat straw, which dilutes the producer gas quality. The ash content is also very high which creates hindrance in the production of producer gas, as it will make clinkers having low heating value. So these raw materials can be used up to a limit only.

4. CONCLUSIONS

The important findings on the engine performance and electric power generation in dual fuel mode of operation while using different agricultural residues (wheat straw & rice straw) in the gasifier are given below:

1) A diesel engine can work successfully in dual fuel operation mode with a suitable biomass in the gasifier.
2) The same amount of power, which is produced by using diesel, can also be obtained by using dual fuel.
3) Producer gas is generated by using the waste biomass feed stocks. Hence the power generation cost while using biomass is less than the power generation cost using diesel.
4) The captive power generation plant can be installed depending on the availability of local biomass, which may help to decrease the import of crude oil in the country.
5) Besides reducing the dependence on fossil fuels, biomass energy helps to decrease environment pollution also. Low levels of sulphur and ash in biomass prevent acid rain formation. Biomass combustion produces less CO_2 and SO_2 as compared to conventional diesel. So, biomass does not contribute to global warming.

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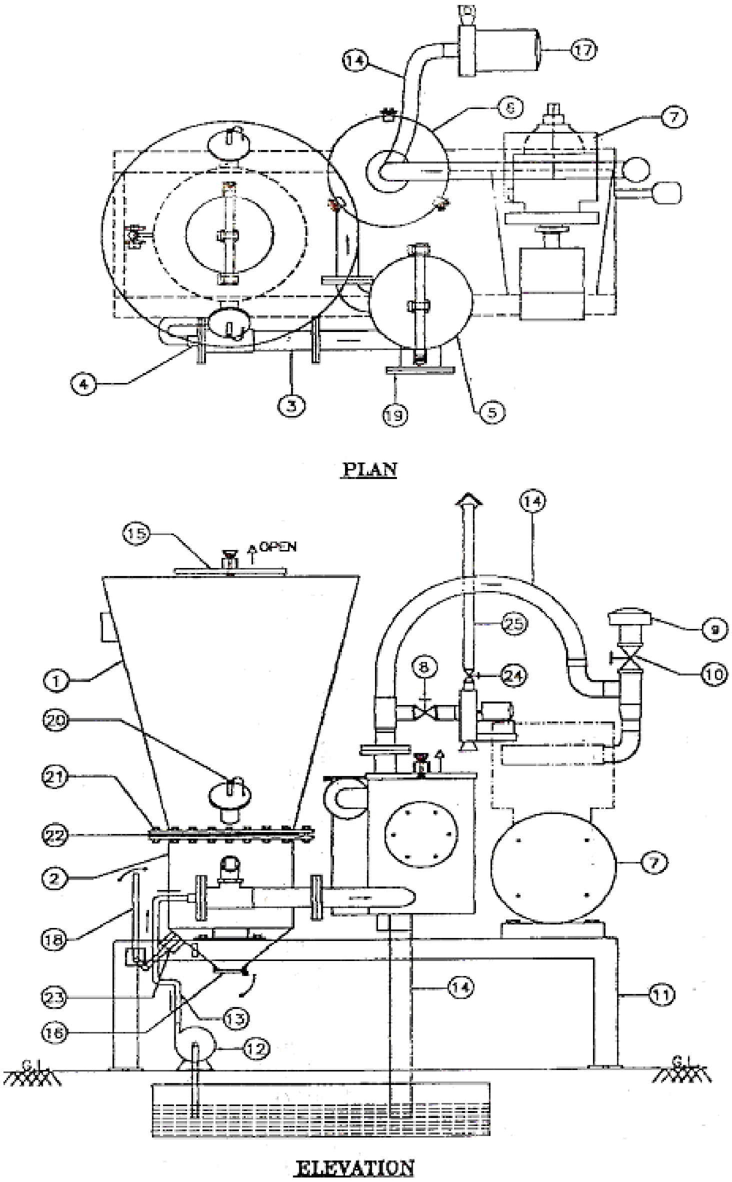
Appendix



SR. NO.	DESCRIPTION
25	FLARE ASSEMBLY
24	FLARE VALVE 1"ø
23	GLAND SEAL OF ASH REMOVAL MECHANISM
22	SEALING ROPE
21	HOPPER–REACTOR FLANGE BOLTS
20	AIR NOZZLE PLUGS
19	FILTER MEDIA DISCHARGE PORT
18	ASH REMOVAL MECHANISM LEVER
17	BLOWER
16	ASH DISCHARGE DOOR
15	FEED DOOR
14	2"øPVC HOSE
13	3/4"øPVC HOSE FOR SCRUBBER
12	WATER PUMP
11	MOUNTING STAND
10	AIR CONTROL VALVE
9	AIR FILTER
8	2" BALL VAVLE
7	D.G. SET
6	CHECK FILTER
5	SEPARATOR BOX CUM FINE FILTER
4	WATER NOZZLE ASSLY.
3	VENTURI SCRUBBER
2	REACTOR
1	HOPPER

Fig. I: Biomass gasifier used for experiment