Biogasifier

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Abstract

The world is facing a great problem of energy crises, because of overuse of conventional fuels in automobiles, power generation and various thermal applications. Imposition of emissions norms by government regulating bodies to reduce environment pollution lead to the search for cleaner burning fuel. Wood gas is expected to play an important role in meeting the existing gap between the energy supply and energy demand, particularly in rural areas, in the present context of energy crises. The technology of Biomass gasification has existed from more than seventy years.The gasifier is a unit which produces inflammable gases by the pyrolysis of wood and similar biomasses. The present project is an attempt to design a gasifier and its accessories and fabricate it to run an AC generator by fueling a spark ignition engine. The gasifier is developed consisting of cyclone filter, particle filter and a cooling system. The wood gas is a result of decomposition of biomass at elevated temperatures to produce a range of inflammable gases, the presence of tar and water vapour in the gas causes deterioration of fuel quality and decrease in output. This is regulated by using a counter flow cooling system and a set of cyclone and particulate filters.
Keywords: Alternate Fuel, Biofuel, Biogas, Gasification, Pyrolysis

I. Introduction

Modern agriculture is an extremely energy intensive process. However high agricultural productivities and subsequently the growth of green revolution has been made possible only by large amount of energy inputs, especially those from fossil fuels. With recent price rise and scarcity of these fuels there has been a trend towards use of alternative energy sources like solar, wind, geothermal etc. However these energy resources have not been able to provide an economically viable solution for many applications.

Recognizing the limitations of many current non-conventional fuel production technologies, in terms of resource potential, greenhouse gas savings and economic viability, there is considerable interest in second generation routes. These offer the potential for a wider range of feed stocks to be used, lower greenhouse gas impacts, and lower costs. Gasification is an important component of several of the proposed second generation routes, such as catalytic routes to diesel, gasoline, naphtha, methanol, ethanol and other alcohols, and syngas fermentation routes to ethanol. In biomass gasification itself, there is greater experience with gasifiers for heat and power applications than for fuels production.

One biomass energy based system, which has been proven reliable and had been extensively used for transportation and on farm systems starting from World War II is wood or biomass gasification.Biomass gasification, viewed today as an alternative to conventional fuel. In gasification process, wood, charcoal and other biomass materials are gasified to generate so called ´producer gas´ for power or electricity generation.

II. Literature survey

A downdraft gasifier at laboratory scale was developed and tested for the presence of producer gas. The construction of the gasifier was based on the design proposed by Fema. The various parts of the gasifier like reaction chamber, fuel hopper, and gas outlet and air inlet were designed. The gasifier was ignited by a flame torch.In the reactor, both gas and biomass feedstock move downward as the reaction proceeds. While biomass flows because of gravity, air was injected with the help of a blower. Experiments were conducted to obtain fluid flow characteristics of the gasifier [1].

An experimental study was carried out on producer gas generation from wood waste in a downdraft biomass gasifier. Then sesame wood or rose wood as biomass. They observed that biomass consumption rate decreased with an increase in the moisture content and it increased with an increase in the air flow rate. The performance of the biomass gasifier system was evaluated in terms of producer gas composition, the calorific value of producer gas, gas generation rate, zone temperatures and cold gas efficiency [3]. Thermocouples were placed inside the gasifier at different locations to measure the temperature of various zones of gasifier. They found the producer gas composition using gas chromatograph. Characteristics of hydrogen produced from biomass gasification were studied. They used a self-heated gasifier as the reactor and char as the catalyst.

Producer gas with low calorific value was used as an engine fuel. Experiment shows that engine ran smoothly at compression ratio 17:1 without any tendency of auto-ignition. Experiments were also conducted on multi-cylinder spark ignition engine modified from petrol engine at varying compression ratios from 11.5:1 to 17:1 by retaining the combustion chamber design [2].

III. THEORETICAL BACKGROUND

Gasification is a thermo-chemical process by which carbonaceous (hydrocarbon) materials (coal, petroleum coke, biomass, etc.) can be converted to a synthesis gas (syngas) or producer gas by means of partial oxidation with air, oxygen, and/or steam. The device which performs this work is known as gasifier. A hydrocarbon feedstock (biomass) is fed into a high-pressure, high-temperature chemical reactor (gasifier) containing steam and a limited amount of oxygen. As biomass flows through the reactor it gets dried, heated, pyrolysed, partially oxidized and reduced. Under these “reducing” conditions, the chemical bonds in the feedstock are severed by the extreme heat and pressure and producer gas is formed. The main constituents of producer gas are hydrogen (H_2) and carbon monoxide (CO). In short, the task of gasifier is to pyrolyze the biomass to produce volatile matter, gas and carbon and to convert the volatile matter into permanent gases, CO, H_2 and CH_4. Producer gas derived from biomass can be used in IC engine with some modifications. Spark ignition (SI) engine can be made to run entirely on producer gas and compression ignition (CI) engine replaces 60% - 80% fuel oil by using producer gas.

Digestion, gasification, incineration and steam generation are some of the available processes for the conversion of biomass into energy. But, gasification is the best conversion alternative in the following view:

1) Gasification offers high flexibility in terms of various biomass materials as the feedstock.
2) Gasification has thermo-chemical conversion efficiency in the range of 70% to 90% which is the highest among various alternative.
3) Gasification output capacity, especially in the high output ranges, is controlled only by availability of adequate feed materials rather than other technical conside

IV. CONCEPTS

A. *Reaction Chemistry Of Gasification*

The combustible substance of a solid fuel is usually composed of elements carbon, hydrogen and oxygen. The producer gas is formed by the partial combustion of solid biomass in a vertical flow packed bed reactor. In the conventional theory of producer gas, gasification reaction takes place in four zones. They are oxidation, reduction, pyrolysis and distillation zones.

B. *Oxidation*

In the oxidation zone, the oxygen in the air-stream reacts with the carbon and hydrogen in the fuel to reduce carbon and hydrogen to form carbon dioxide and water. Carbon dioxide is obtained from carbon and water is obtained from the hydrogen in the fuel.

$$C + O_2 = CO_2 \text{ (+393 MJ/kg mole)} \quad (1)$$

$$2H_2 + O_2 = 2H_2O \text{ (-242 MJ/kg mole)} \quad (2)$$

Reaction (1) is known as combustion reaction. The oxidation reaction is exothermic and this heat is supplied to the neighbouring zones i.e. reduction zone.

C. *Reduction Zone*

The partial combustion products CO_2, H_2O obtained from oxidation zone are now passed through reduction zone. Here CO_2 and H_2O are reduced to form carbon monoxide (CO) and hydrogen (H_2) by absorbing heat from the oxidation zone. Oxidation zone raise the temperature of reduction zone to promote the carbon/steam gasification reaction which has higher activation energy. This reaction requires temperature of 900^0C and above. Over 90% of CO_2 is reduced to CO at temperatures above 900^0C.

$$C + CO_2 = 2CO \text{ (- 164.9 MJ/kg mole)} \quad (3)$$

$$C + H_2O = CO + H_2 \text{ (- 122.6 MJ/kg mole)} \quad (4)$$

Reaction (3) is known as Boudouard reaction. Reaction (4) is the water gas reaction and it is very important in gasification as it can enrich the gas manufactured with hydrogen, thus enhancing its calorific value. The other reaction with carbon/steam gasification occurs at lower temperature between 500-600^0C.

$$C + 2H_2O = CO_2 + 2H_2 \text{ (-88 MJ/kg mole)} \quad (5)$$

A further steam reaction in gas producer with excess of steam is water gas shift reaction. This should be avoided as it reduces the cold gas efficiency, though it reduces the carbon monoxide which is highly toxic in fuel gas distribution for public use.

$$CO + H_2O = CO_2 + H_2 \text{ (+42 MJ/kg mole)} \quad (6)$$

Other reaction occurs in char at temperature about 500^0C are

$$C + 2H_2 = CH_4 \text{ (+75 MJ/kg mole)} \quad (7)$$

Reaction (7) is known as methane reaction and it is an exothermic reaction.

D. *Pyrolysis Zone*

In pyrolysis zone, up to the temperature of 200^0C only water is driven off and between the temperature 200 to 280^0C carbon dioxide, acetic acid and water are given off. The real pyrolysis, starts between 280 to 500^0C, produces large quantities of tar and gases containing carbon dioxide. Besides light tars, some methyl alcohol is also formed.

E. *Distillation Zone*

In the distillation zone, raw fuel like tar is preheated and carbonized giving of condensable and non-condensable gases. Produces much more tar than downdraft one because in downdraft gasifier the tars have to go through combustion and reduction zone and are partially broken down.

V. DESIGN AND DEVELOPMENT

A. *Components of Gasifier*

In the present work, downdraft gasifier is used for producer gas generation, because it produces less tar compared to updraft gasifier. Since the gasifier has to couple with petrol engine for performance and emission and combustion test hence producer gas from gasifier must content as less tar as possible because higher tar content fuel gives rise to corrosion effect which is a major cause of damage to engine components like piston, valve etc. Hence downdraft gasifier is the most appropriate for the above application. Main components of downdraft gasifier and their design are described below.

1) *Hopper*

The purpose of a hopper is to store the biomass for continuous feed to reaction chamber. It is mounted above the reactor of gasifier. The fuel storage hopper is made up of 2mm thick mild steel. The diameter and height of fuel hopper is chosen to be 105mm and 460mm respectively. Round shaped hopper has been chosen to prevent the problem of biomass being stuck. Fig 1 shows the isometric view of a hopper.

Fig. 1: Isometric front view of hopper

The hopper is designed to withstand the excess temperatures produced at the time of pyrolysis. The hopper is loosely packed with wood shavings .The approximate amount of air to be supplied through the hopper is 0.9 m3per min.Thus the air entering into the hopper should have velocity lager than 1.8m/s.

2) *Gasification Zone*

Gasification zone is an integral part of the hopper. It extends to 420 mm beneath the hopper. The air inlet pipe made of mild steel of 10mm diameter are attached into the gasification zone and extends outside the zone further from where the pipes take a 900 turn. Further beneath the gasifier the gasification zone is reduced to 60mm using a metal ring. The purpose of the ring is to provide a reduction in the gasification zone which has many positive effects on overall gasification performance.

3) *Grate*

A perforated grate made of mild steel of thickness 5mm and circular diameter of 110mm is attached on to the gasification zone using chains. The grate is placed at 15mm distance below the reduction of the gasification zone. Fig 2 and Fig 3 shows the front view and isometric view of grate respectively.

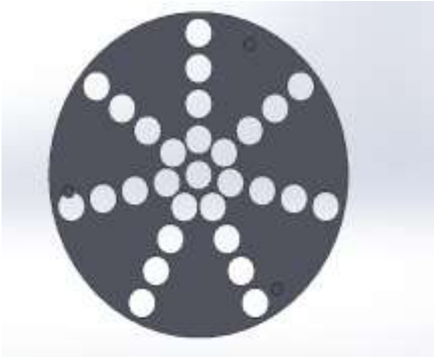

Fig. 2: Grate front view

Fig. 3: Grate isometric side view

4) Gasifier Casing

It is a steel sheet metal drum of diameter of 250mm and at a height of 500mm. An opening for firing and grate shaking is placed at a distance of 80mm above the bottom of the casing. And an opening for ash removal is provided beneath the gasifier casing. Fig 4, Fig 5 and Fig 6 shows the side view, front view and topview of gasifier unit respectively.

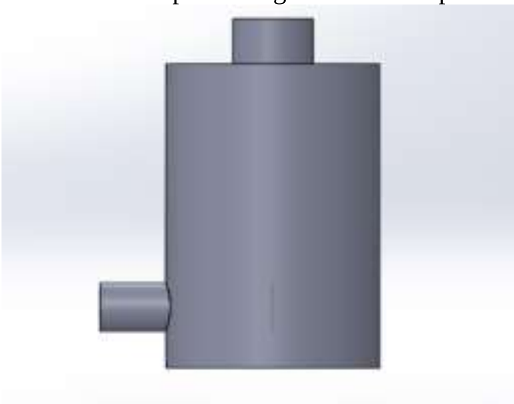

Fig. 4: Side view of gasifier unit

Fig. 5: Front view of gasifier unit

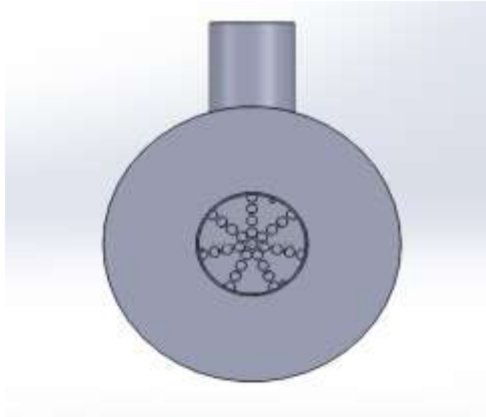

Fig. 6: Top view of gasifier unit revealing grate

B. Filteration Systems

Filteration system is a very most important part of the entire gasifier unit. The system helps to remove a large percentage of particulate matter and potentially hazardous and corrosive tar produced during the partial combustion of the wood. Following are its components.

1) Cyclone filter

Cyclone filter is made of Galvanized iron sheet metal of 1mm thickness. The filter is of conical shape at the wider side being of 250 mm in diameter and the narrower end being 90mm in diameter. The height of the filter is 270mm. A deposition container of diameter 88mm and height of 100mm is fixed under the filter.

The inlet of the filter placed tangentially though the walls of the filter at a distance 20mm below the top of the filter. The outlet of the filter is made of GI pipes of diameter 30mm is axially placed in the filter and starts from the narrow end of the filter and exits the same from the wider end. and Fig 7 shows the isometric view of cyclone filter respectively.

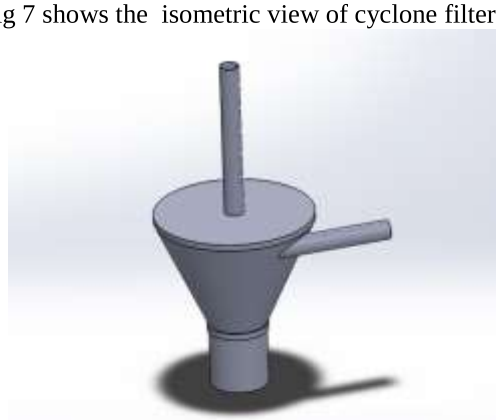

Fig. 7: Isometric side view of cyclone filter

2) Particulate Filter

Particulate matter filter was a plastic drum having removable lid. The container dimensions are as follows254 mm in diameter and 304 mm in height. The filter is loosely packed with wood chips and the inlet and the exit are covered by steel and sponge meshes. Fig 8 shows the particulate filter. The wood chips and meshes can be seen in the Fig.8

Fig. 8: Loosely packed wood chips in the particulate filter

C. Cooling And Condensing Unit

The procedure used here is simply dividing the syngas into two separate paths and cooling them individually for better efficiency of cooling. Either running water or stagnant water can be used. The inlet and outlet ports are provided on the ends of both pipes.GI pipes carrying the syngas is immersed in a larger diameter PVC pipes for this process. Fig 9 shows the side view and isometric view of cooling unit and Fig 10 shows the front view of cooling unit.

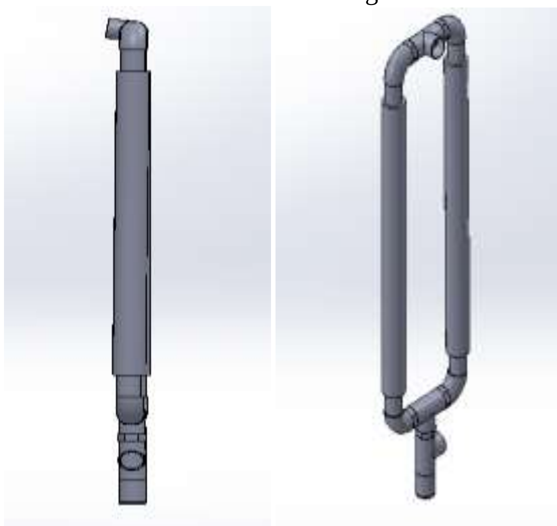

Fig. 9: Side view and isometric view of cooling unit.

Fig. 10: Front view of cooling unit

D. Working Model

Fig 11 shows the working model of the gasifier unit. The unit consist of gasifyng chamber, particulate filter, cyclone filter, condensing unit, generator, blower etc.

Fig. 11: Working model of gasifier unit

VI. EVALUATION AND ANALYSIS

A. Process Initialisation

The gasification process consist of serious of steps which include initial firing, and charging.The processes are explained below.

1) Initial Firing

The hopper is initially charged with wood chunks. The wood chunks are approximately filled to a height of about 50mm from the grate at the bottom of the hopper. Meanwhile the air is allowed to be sucked out from the gasifier unit using an air blower assembly attached to the end of the gasifier unit. The air is sucked in to the gasifier casing through the opening of the hopper. This makes sure that ample amount of air is supplied o the wood chunks on the grate. The wood chunks are fired and ignited. The blower ensures the required oxygen supply on the burning wood. The wood is allowed to burn red hot.

2) Charging

The hopper is further filled with the wood shavings till the brim, it is ensured that the wood is loosely packd at the time of charging. The charging ensures limited oxygen supply into the hopper.

3) Checking of the Fuel Gas

The fuel gas is being pumped out through the blower exit. The gas is pumped until the color of the gas starts diminishing from thick white. Once the gas becomes colorless the gas is checked for firing capability. The gas from the blower outlet is fired using a gas lighter.

B. Petrol Vs Woodgas

Wood chips and shavings are used as a feed stock for gasification. It is a renewable source of energy and easily available at large scale. Wood chips can be collected from furniture shop, and it is one kind of waste for shop keeper and they used to through it as it is. Table 6.1 shows the composition of wood chips. Carbon, oxygen and volatile matter occupies the highest concentrations.

Table - 1
Properties of wood chips

Property	Wood Chips
Carbon (%)	48.6
Hydrogen (%)	6.5
Oxygen (%)	40
Nitrogen (%)	7.26
Sulphur (%)	0.05
Ash content (%)	3.90
Moisture content (%)	6.57
Volatile matter (%)	86.2
GCV (MJ/kg)	18.06

VII. CONCLUSION

The performance and exhaust emission characteristics were investigated experimentally in a single cylinder, 4-stroke SIengine operating with gasifier unit with woodchips as fuel and following conclusion were made on the basis of present work.

1) Higher amount of petrol fuel can be saved by replacing petrol with producer gas although there would be a reduction in brake thermal efficiency which is due to lower heating value of producer gas and insufficient amount of oxygen supply.
2) NO emission was found to be very low in syngas fuel which is a great advantage of syngas fuel over petrol fuel alone.
3) CO and HC emission was observed very high in producer gas which gives an indication of insufficient oxygen in combustion chamber.Gasification technology is theoretically an interesting option for rural development.

It promises:

1) Sustainable conversion of locally available biomass into electricity for local supplies.
2) Local value chain with income generation for the suppliers of the biomass as fuel.
3) Incentives for reforestation.

Hence it will remain on the energy development agenda.Each new plant would be a unique tailor-made facility. The main preconditions for a successfully operating gasification plant are:

1) Major obstacles (economic or environmental) for the use of other fuels (fossil or renewable) or forms of energy
2) High and constant availability of cheap appropriate biomass fuel
3) Availability of an experienced manufacturer

4) Continuous availability of specialized know-how for maintenance and operation that is not to be financed through the operational profit (for example, possible in co-operation with research projects.
5) Low labour costs;
6) Sufficient economic potential of the electricity users to cover at least the operational costs.

Additional conducive conditions would be:

1) Besides electricity use, heat or other by-products of the system can be sold or used in a profitable way.
2) Positive side effects such as providing an incentive for reforestation, reducing GHG emissions etc. justify considerable subsidies.
3) Initial capital does not have to be repaid directly by the consumer of the electricity produced; subsidies are in place.

At the current stage, the technology may be a reasonable solution in some industrial settings where continuous qualified technical support can be guaranteed.

Acknowledgment

First of all, we thank God Almighty for His abundant grace and mercy which enabled me in the finalization of this project. The support and help of a few people not only enabled us to complete our project successfully, but also made it a worthwhile experience. We thank the management for providing all the infrastructure and facilities. We are grateful to Dr.M.C.Philipose, Principal, SAINTGITS College of Engineering for providing the best facilities and atmosphere for doing this project. We thank Dr.Sreejith C.C, HOD, Mechanical engineering, for his encouragement and support. Also we thank our project guide Asst. Prof, Parvathy Venugopal, Dept. of Mechanical engineering for her valuable suggestions, ideas and support without which this project would have been a dream. Finally, we thank all the staff members of our department for their timely help and guidance.

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