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Fabrication and Evaluation of a Downdraught Gasifier Running with Biomass for Sustainable Agriculture

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Abstract

Energy shortage is the major problem for Pakistan's Economy. This problem can be solved by using the alternative/renewable sources of energy; the best alternative source of energy is producer or syn gas. There are large amounts of biomass available in our country in the form of crop residue. Pakistan is producing millions of tons of biomass annually in the form of crop residue, rice husk, and wood mills waste, cotton processing waste and corn pith, which can be easily used in the production of syn or producer gas. The research work was conducted in the Workshop, Department of Farm Machinery & power, Faculty of Agricultural Engineering and Technology University of Agriculture, Faisalabad, Pakistan in 2008-09. In this research work fabrication and evaluation of a downdraught gasifier with different solid fuels like Coal, Charcoal and Corn Piths was carried out for 12 kW single cylinder engine. The amount of gas produced by equal weight (18 kg) corn pith was 35 m^3, by charcoal was 41m^3 and by coal was 39.7m^3. This gas was sufficient to operate an engine of 12 kW which require 39.6 cubic meter per hour. the consumption of gas will be reduced when it runs a dual fuel engine (Diesel Engine).

Keywords: Biomass, Gasifier, evaluation, fabrication

Introduction

Producer/syn gas is a best alternative/renewable source of energy. The material used for the production of producer or syn gas is biomass. The biomass is easily available and its cost is very low. The cost for the construction of a gasifier is very less and can be constructed very easily as compared to other sources of energy. The material used for its construction is also easily available at local markets. The producer gas can be used in all types of engines and for the production of electricity. It can be easily used at farms for running of a tube well engine. Pakistan is an agricultural country. In Pakistan almost all the crops are grown. Wheat, Rice, Corn, Sugarcane, Cotton are the major crops grown in the country. These crops are grown on a large area and produce a huge amount of biomass. From these crops we can get a huge quantity of biomass which can be used in the gasifier. Agricultural waste (crop residue) from corn and cotton is best suitable fuel for a gasifier.

The combustible gas production from carbon containing materials i.e. biomass is very old technology. For many years the coal gas was used for cocking and heating. It was first practiced in 1812 when City-Gas Company of London started production of syn gas. In 1840 first commercially used gasifier was built in France. The real breakthrough was made in 1861, when Siemens gasifier was introduced. That unit is considered to be the first successful gasifier in history. The first 600 horse power engine operating with producer gas was exhibited in 1900 at Paris. In 1939, about 250,000 vehicles were registered in Sweden, out of them about 90% were converted to the producer gas drive and almost all of the 20,000 trucks were operated on producer gas using wood and charcoal as fuel(Rajvanshi, 1986). Gasification involves an incomplete combustion of a low valued hydrocarbon stream in an oxygen deficient or reducing atmosphere. Gasification can use only 20 to 30 % of the theoretically required oxygen for complete combustion. The process operates at high temperature and includes the use of oxygen and process steam in conjunction with the fuel. When undertaken with air as oxidizing agent the producer gas has a net calorific value (NCV) of about 46MJ/m^3 to 48 MJ/m^3 (Jerod and Brown, 2003). The heating value of this gas makes it suitable for use in the IC engines. When oxygen is used, the producer gas has a NCV of 10-15 J/m^3, sufficient for limited pipeline transport and synthesis gas conversion (Jerod and Brown, 2003).Gasifier is a plant or reactor in which the producer or syn gas is produced by burning of the solid fuel. Gasifier is providing suitable circumstances for pyrolysis in biomass and passage for the flow of gas produced in the pyrolysis.

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Downdraught gasifiers being comparatively easy to build and operate are likely to be most appropriate for our conditions. The design of downdraught gasifier is simple and easy to construct. Producer gas requires no major modifications of existing engines. To fuel existing spark-ignition engines with producer gas requires only a minor replacement or attachment to the carburetion system. Producer gas requires no unconventional technology such as is required by electric, steam or sterling engine-powered motor transport. When we used it in the compression-ignition engine we need only minimum supply of diesel to operate the engine.The system that makes producer gas has four main components.

A reactor to make producer gas from the solid fuel

A cleaner to filter the sot and ash from hot gas

A cooler to condense the tar and other liquid impurities

A valve to mix the producer gas with air, as well as a throttle valve to meter the mixture into the engine intake manifold.

Objective

To design and fabricate a downdraught gasifier to run 12 kW engine.

To test and evaluate the gasifier for coal, charcoal and corn pith (Corn Cobs).

Materials and Methods

Downdraught gasifiers being comparatively easy to build and operate are likely to be most appropriate for developing countries as a source of decentralized power supply to rural communities and small industries. The conversion of solid biomass to gaseous fuel in a downdraught gasifier and evaluation was examined in the Agricultural Engineering Workshop Faculty of Agricultural Engineering and Technology, University of Agriculture, Faisalabad in detail.

The dimensions of gasifier were closely related with "Hearth Load" concept. Hearth load is defined as the amount of producer gas reduced to normal (Pressure and Temperature) conditions, divided by the surface area of the "throat" at the smallest circumference (Brandini,1983). It is expressed in $m^3/cm^2/h$. Alternatively the hearth load can be expressed as the amount of dry fuel consumed, divided by the surface area of the narrowest constriction (B_s), in this case the hearth load is expressed in $Kg/cm^2/h$. because one kilogram of dry fuel under normal circumstances produces about 2.5 m^3 of producer gas, the relation between B_g and B_s is given by:

$B_g = 2.5\ B_s$

According to information provided by Brandini Bg may reach a maximum value of about 0.9 (Bs= 0.36) in continuous operation in good "Imbert" types gasifiers. High values of Bg may give rise to extreme pressure drop over the reduction zone of the gasifier. Minimum values of Bg depend essentially on the heat insulation of the heat zone. Below a certain hearth load the temperature in the hot zone is lowered so much that tar production becomes inevitable. Normally generators show minimum values of Bg in the range of 0.30 – 0.35, resulting in power turn down ratios of a factor of 2.5–3.

The gasifier was designed for running a 12 kW single cylinder diesel engine having swept volume of 750cc.

The swept volume of the engine = 750cc.

The maximum rpm of this engine = 2200

Engine Volume swept in one stroke = 750 cc

4-stroke engine intake air/gas mixture once in two revolutions, i.e.

Gas/air intake in two revolutions = 750 cc

Maximum gas/air intake for 1500 rpm = 1/2 (2200 rpm) (750 swept volume) = 825000cc/ min

Actual air/gas intake = 825000(A) cc/min

(A = volumetric efficiency)

For a well designed and clean air inlet manifold "A" = 80%

Actual air/gas intake = 660000 cc/min

The air gas stoichiometric ratio = 1.1:1

Max. air/gas intake = 1/1.1 (660000)

= 600000 cc/min = 36 m^3/hr

From Hearth Load concept the gaseous Hearth Load = 0.9,

So

Area of throat at narrowest portion = 36/0.9 = 40 cm^2

Diameter of throat

$= (4 \times 44/3.14)^{1/2} = 7.14$ cm

Height of nozzle plane above smallest cross-section of throat was taken from the empirical data presented by the Swedish Academy of Engineering Sciences (SAES). For 7.48 cm diameter the height will be 8.21 cm (Fig.1). For this diameter and gas requirement 4 nozzles of 1 cm diameter each was used as presented by SAES.

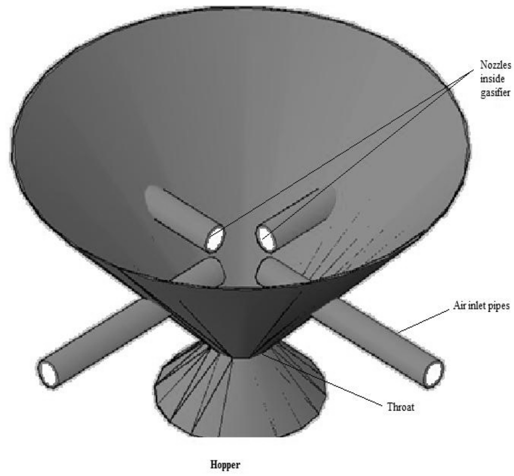

Figure 1 Schematic diagram of throat section.

The gasifier was made by MS sheet of 20 gauge in cylindrical shape of 60.96 cm diameter and 91.50 cm in height. A 10 cm round opening was provided at the top of gasifier for feeding the biomass. A throat with a slope of about 50º (standard) and 7.48 cm diameter at the narrowest section was fastened in the gasifier. Four sided air inlets opposite to each other were provided for air supply in pyrolysis zone at a height calculated according to Hearth Load Concept. A 3.8 cm diameter pipe was provided under the grate for exhaust of producer gas. A 12.7 cm diameter in diameter ash removal hole with air tight cap was provided just above the bottom of gasifier.

For the cooling and cleaning purposes water cooling/cleaning system was used. For this purpose a cleaning unit was designed with dimensions of 61 cm in diameter and 83 cm in height. At the top of this unit, two hollow cone nozzles were installed for shower of water. These were spray water from top on hot raw gas coming from gasifier in the cleaning drum from bottom and were leave the drum from top and the water with impurities was removed from bottom of the unit (Fig.2). In second stage of study, the gasifier was evaluated by using coal, charcoal and pith (corn cobs). It was tested for the temperature and composition of syn gas produced with these fuels. The running time and volume of gas produced by each fuel with same quantity was noted.

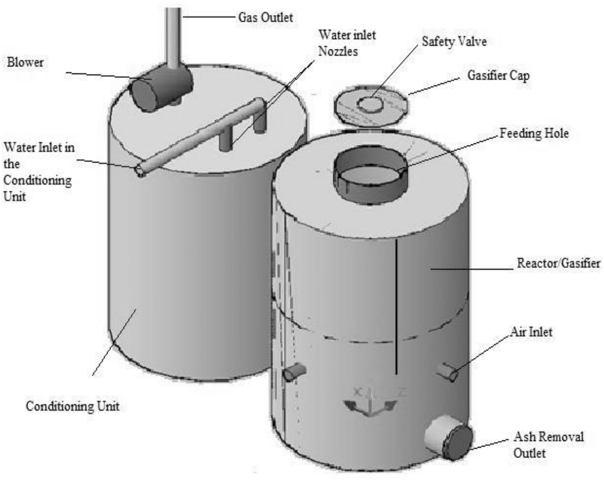

Figure 2 Schemativ diagram of Gasifier

Data collected was statistically analyzed using CRD design. PROG GLM (General Linear Mode) procedures of the SAS System (1989) were used to analyze the data. When the F-test indicates statistical significance, treatment means were separated by the LSD test (Steel and Torrie, 1984).

Results and Discussion

Gasification or pyrolysis offer more scope for recovering products from waste than incineration. When waste is burnt an a modern incinerator the only practical product is energy, whereas the gases, oils and solid char from pyrolysis and gasification can not only be used as a fuel but also purified and used at feedstock for petro-chemicals and other applications. Many processes also produce a stable granulate instead of an ash, which, can be more easily and safely utilized. From crop waste gasification, in particular, it is feasible to produce hydrogen, which may see as an increasingly valuable energy resource.

In this research the parameters like production of Carbon dioxide, Carbon monoxide, sulpher dioxide, Nitrogen dioxide, Nitric oxide, running time and volume of gas produced with equal quantity of different types of fuel were tested. The fuels used for this evaluation were Pith (Corn Cobs), Coal and Charcoal.

The data then statistically analyzed on personal computer by using PROG GLM (General Linear Model) procedures of the SAS systems (1989). The following results were obtained at 5% level of significance.

Running Time

The duration for same quantity (18 kg) of each fuel burning in the gasifier was noted with the help of stopwatch.

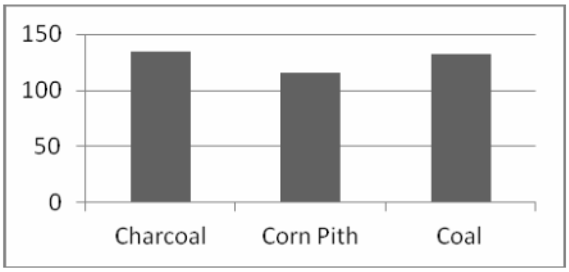

Figure 3 Gasification time for same mass of different fuels (minutes)

The Fig. 3 shows that the running time of gasifier using charcoal as fuel was more (134.5 min) than running of the gasifier with corn pith (115.5 min) and coal (132.25 min). The mean values of charcoal and coal are not significantly different as compared to pith may be due to the difference in the calorific values of the fuels or due to particle size of the fuel. Charcoal, specifically, because of being tar free and having relatively low ash content property, more volatile matter and more running time as compared to other fuels was the preferred fuel during the World War II and remains so (Remulla,1982).

Volume of Gas Produced
The volume of producer gas produced by the gasifier was measured by the following formula
Vol. of Gas Produced = Time (sec) * area of pipe (m^2) * velocity of gas (m/s)
The velocity of the gas leaving the blower pipe was measured with the anemometer and time was recorded with stopwatch.

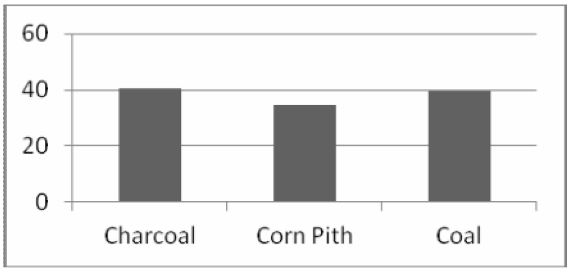

Figure 4 Volume of Gas Produced (m^3)

The Fig.4 reveals that the treatment Charcoal produced the more volume of gas 40.35 m^3 as compared to the other treatments. The Coal comes at second number which produced 39.67 m^3 of gas and the pith was at third number which produced 34.65 m^3 with the same quantity of the fuel. This may be due to the reason that the pith has low bulk density and difference in the calorific values as compared to coal and charcoal. The charcoal, pith and coal have calorific values of 5.95, 6.29 and 4.60 Mj/m^3 respectively in the downdraught gasifier (Solar Energy Research Institute, 1979).

Carbon Monoxide (CO)
Carbon monoxide is a combustible gas in the producer gas. However, it is a highly poisonous gas and rapidly reacts with the oxygen present in the human blood. Its quantity depends upon the combustion of the fuel; if the fuel is fully burned in the gasifier then its quantity will be very low.

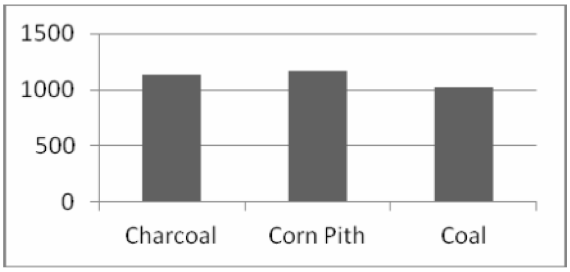

Figure 5 Carbon Monoxide produced by different fuels used for gasification (ppm)

The Fig. 5 showed that the charcoal produced 1137.5 ppm of CO while Pith produced 1166.0 ppm and the coal produced 1017.75 ppm Carbon Monoxide gas in the producer gas. The difference in the amount of CO may be due to the presence of volatile matter in the fuel. Its quantity depends upon the combustion of the fuel; if the fuel is fully burned in the gasifier then its quantity will be very low. But if the burning of the fuel is take place in the combustion zone in controlled atmosphere (incomplete combustion) then its quantity should be more in the producer gas (Schapfer and Tobler, 1937).

Carbon Dioxide (CO_2)
Carbon dioxide produced in the gasification operations in very less amount. In the case of complete combustion (excess air in oxidation zone) of the fuel in the gasifier, the carbon monoxide reacts with excess air and converted in to carbon dioxide. If the amount of the oxygen is controlled then the amount of carbon dioxide significantly reduced in the producer gas (Skov and Paperworth, 1974).

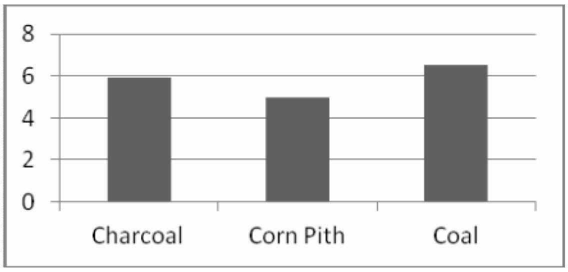

Figure 6 Carbon Dioxide produced by different fuels used for gasification (ppm).

Fig.6 indicated that the means of all treatment were not significantly different from each other. The mean CO_2 production in the producer gas was 5.90, 5.00 and 6.52 for charcoal, pith and coal respectively. The production of carbon dioxide in the gasifier is not the property of the fuel; it is only the function of the controlled amount of air supply to the gasifier. A controlled amount of air/oxygen effects the production of the carbon dioxide because it forms only when the complete combustion of the fuel occurs in the gasification system. Excess amount of the oxygen reacts with the CO and converted it into CO_2.

Sulphur Dioxide (SO_2)
SO_2 is a non-combustible, colorless and toxic gas present in the producer gas. The statistically analyzed data indicates that the production of the sulphur dioxide in the producer gas was significantly differing in each fuel. This may be due to the presence of the sulphur contents in the fuel.

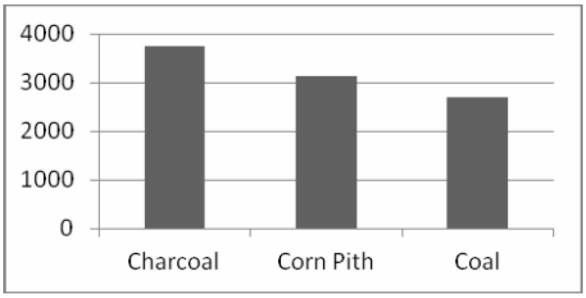

Figure 7 Production of Sulphur Dioxide during gasification of same mass of different fuels (ppm)

The Fig.7 indicated that the average sulphur dioxide produced with the charcoal was 3756.5 ppm, which was very high as compared to pith (3141.8) ppm and the coal (2700.5) ppm. The mean of the treatments was 2226.26 ppm. This gas may be converted into sulphuric acid after reacting it with water.

Nitric Oxide (NO)

Nitric oxide is a brown toxic gas which is produced during the gasification process of biomass.

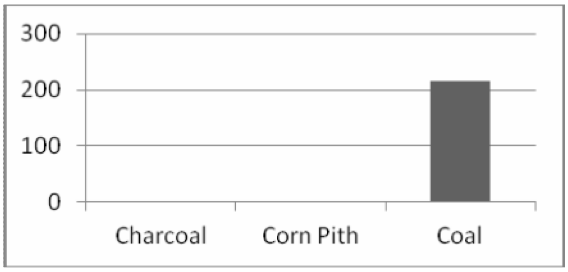

Figure 8 Production of Nitric Oxide (ppm) during gasification of same mass of different fuels (ppm)

The results (Fig. 8) showed that the charcoal and pith did not produce any nitric oxide in the gasification process while the coal produces a huge amount 216.0 ppm in the producer gas. (Gross, 1979) investigated that the burning of the pith (Corn Cobs) in the down draught gasifier did not produce any type of nitrogen oxides.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a toxic brown gas with formula NO_2. It dissolves in water with reaction to give a mixture of nitric acid and nitrous acid. Because of the unpaired electron this is paramagnetic and brown. Nitrogen dioxide along with other nitrogen oxides is a product of combustion engines and is thought to be involved in the depletion of stratospheric ozone. This gas present in the producer gas in less amounts and can be removed from the producer gas with the water shower. The Fig.9 reveals that the quantity of Nitrogen Dioxide in the producer gas was significantly different from each other. The charcoal produced the 198.75 ppm NO2 in producer gas and burning of coal as a solid fuel in the downdraught gasifier was yields 69.75 ppm of NO2 in the producer gas. While the burning of Corn Cobs did not produce any amount of Nitrogen Dioxide. (Schapfer and Tobler, 1937) stated that charcoal and coal, when used as a fuel in the downdraught gasifier produces nitrogen oxides up to 60 percent on volume basis.

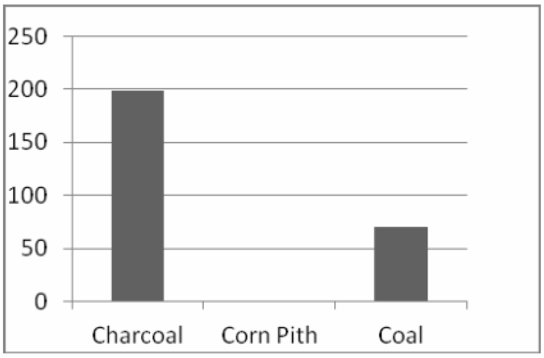

Figure 9 Production of Nitrogen Dioxide during gasification of same mass of different fuels (ppm)

Conclusion

If crop residue or biomass are available in sufficient amount without any danger to forest and animal feed, gasifier can serve as an option for energy supply in remote areas. This technology is decent-ralized energy conversion system which operates economically even for small scale. Mixed with air, the producer gas can be used in gasoline or diesel engines with little modification or in burners. This technology is very good for adaptation especially for villages, sawmills, rice shelling plants and sugar mills where biomass is in excess quantity. The Corn Cobs (pith) can be used without any prior processing. It is cheaper than coal and charcoal and gives almost equal volume of gas as compared to other fuels.

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