A Review Paper on Theoretical & Experimental Investigations of a Dedicated Producer Gas Engine Technology

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Abstract— The world is facing severe problems of energy crisis and environmental problem. This situation makes people to focus their attention on sustainable energy resources for their survival. Biomass is recognized to be the major potential source for energy production. There are ranges of biomass utilization technologies that produce useful energy from biomass. Partial combustion of biomass in the gasifier generates producer gas that can be used for heating purposes and as supplementary or sole fuel in internal combustion engines. Gasification is one of the promising technologies to convert biomass to gaseous fuels for distributed power generation. In this study the performance of the gasifier–engine system is analyzed by running the engine for various producer gas– air flow ratios and at different load conditions.

Key words: Biomass gasification, gasifier–engine system

I. INTRODUCTION

Fulfilling the conventional energy requirement is a biggest challenge of today, and the increasing rate of human facility devices are further adding to energy demand. In today's world fossil fuels or conventional fuels are major sources of energy. But we know that these types of fuels are responsible for global warming and pollution. [1] [20]

Due to resources depleting trend, future energy security is topic of discussion. Renewable energy sources are accompanying human society since existence of mankind.They is Small Hydropower, Solar Energy, Wind Energy, Geothermal Energy, Biomass etc. These Renewable energy sources have potential to solve stated problems. So that I take my area of interest as biomass as non-conventional fuel.[1] [20]

Biomass is available throughout the world which can be converted into useful energy. In our country biomass is an easily available and in abundant form. [2]

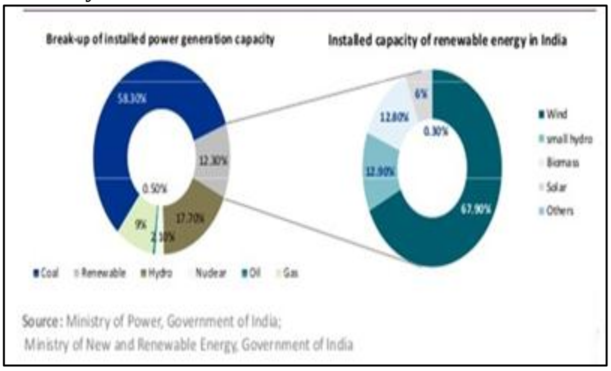

Fig. 1: Installed capacity of renewable energy in India

As per the Ministry of New and Renewable Energy (MNRE), India's total renewable potential is ~245 GW, however the current installed capacity is only 28 GW [4]

Bio energy comprises of bio mass, bio fuels and bio gas. A total of 4,449 MW capacity has been installed in bio energy in both grid connected and off grid capacities in India as on March 31st, 2013 [4]

Biomass based power generation grew at a CAGR of 21.6 percent and increased from 1,112 MW to 3,601 MW between FY07-FY13 [4]

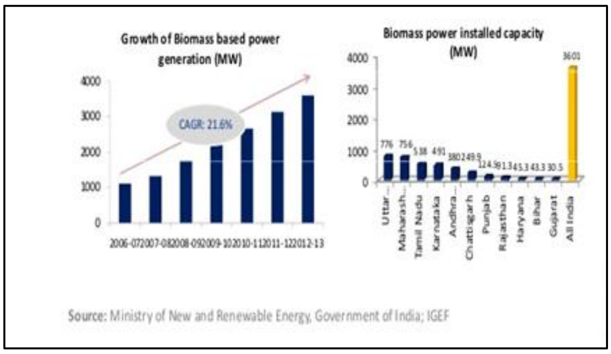

Fig. 2: Biomass power installed capacity (MW)

Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas. Producer gas can be used to run internal combustion engines both compression and spark ignition. The device perform this task is called gasifier. There are two types of gasifier: (1) fixed bed and (2) fluidized bed. According to the way air or oxygen is introduced in gasifier: (1) Downdraft, (2) Updraft, (3) Cross draft. [5]

In recent years, producer gas has become more attractive as an alternative gaseous fuel for internal combustion engines and the fact that it is made from renewable resources. [3]

A spark ignition engine on the whole requires very little modification to run on producer gas. Generally depending upon the make of engine (compression ratio and rpm), the ignition timing has to be advanced by about 30-40 degrees. This is done because of low flame speed of producer gas as compared to gasoline. [3]

In this context, an attempt has been made to review the research studies on this important area.

Properties	Producer gas
Calorific value	7000-8000 KJ/m^3
Laminar flame speed	20-30 cm/s
Peak flame temp.	1800 K
Lower heating value at 1atm and 15°C	3500-6000 KJ/kg
Density at 1atm and 15°C	1.05
A:F ratio	1.2
Auto ignition temp	625°C

Table 1: Properties of producer gas

Compounds	Symbol	Gas (Vol. %)
Carbon Monoxide	CO	15-30
Hydrogen	H2	10-20
Methane	CH4	2-4
Carbon Dioxide	CO2	5-15
Nitrogen	N2	45-60
Water Vapour	H2O	6-8

Table 2: Compounds of producer gas

II. LITERATURE SURVEY

A brief summary of the vast amount of material that has been published on producer gas would be well beyond the scope and intention of this paper. Instead, attention is focused on a few key aspects of producer gas engine technology that are considered important and relevant.

Vinay shrivastava [2] describes in this review, a downdraft gasifier was designed and developed for running a single cylinder, 4-stroke, air cooled, direct injection diesel engine developing a power of 4.4 kW, at a rated speed of 1500 rpm on dual fuel mode. The performance and emission characteristics of the engine were studied at different loads for various gas flow rates. The break thermal efficiency of dual fuel engine is lower than that of diesel engine. The maximum efficiency achieved by diesel fuel was 27.5% where as in dual fuel mode maximum efficiency achieved was 26%, 25% and 24.5% for D+PG 4 lpm, D+PG 6 lpm and D+PG 9 lpm respectively. Specific energy consumption in dual fuel mode was found to be higher than that of diesel mode at all load conditions. Exhaust gas temperature for dual fuel mode is always higher than diesel fuel; this is due to the excess energy supplied to the engine. NOX, CO, HC emissions are found that higher compare to diesel engine. Only NO emission is lower than diesel engine.

Shashikantha, W.Klose, P.P. Parikh [6] shows that a 15 kwe spark ignition producer gas engine (SIPGE) has been developed by machine converting a 17 kwe direct injection diesel engine. This paper reports the development of a simulation model for estimating the in-cylinder process parameters of the SIPGE and an attempt made for its validation. The selection is based on simplicity in conversion, availability of spares, higher excess air capacity to reduce derating etc. Accordingly, a Kirloskaa make, RB 22 model, twin cylinder, vertical, water cooled, direct injection diesel engine is selected. Its stroke = 110 x ll0mm, rating = 17 kwe at 1500 rpm, compression ratio = 17:1, excess air provision = 30%, volumetric efficiency = 80%, squish area = 69% and bumping clearance = 1.3 mm. The modifications carried out are change in combustion chamber geometry - both shape and size, reduction of compression ratio, incorporation of ignition system, fitment of spark plugs, and mounting of an air-gas mixer. The compression ratio reduced from 17 to 11.5:1. The plugs are fitted through the holes left out by replacement of injectors on the cylinder head and are located almost centrally in the combustion chamber. A venturi type air-gas mixer has been designed and mounted at the engine inlet. It is reported (Shashikantha et al., 1992) that the SIPGE delivers 15 kWe with thermal efficiency of 28-32%. The peak temperatures are 2422 K at burned mixture temp., 1019 K at unburned mixture temp., and 821 K at motored mixture temp.

Felipe Centeno, Khamid Mahkamov, Electo E. Silva Lora, Rubenildo V. Andrade [7] performs on a mathematical model which was developed to predict steady state performance of a biomass downdraft gasifier/spark ignition engine power system is described. This requires a fixed bed downdraft gasifier and SI internal combustion engine. For calculations the gasifier is split into three zones, namely drying, pyrolysis, oxidation and reduction sections. The gasifier's mathematical model consists of three separate sub-models, each describing the processes in the corresponding zone. The proposed model is applicable for modeling integrated downdraft gasifier/engine biomass energy systems and can be used for more accurate adjustment of design parameters of the gasifier and the engine in order to provide the higher overall efficiency of the system. The numerical results obtained from the coupled modeling of the gasifier and the engine as a whole biomass energy system can be used for the refined adjustment of design parameters of these two major components and to achieve the improved overall efficiency in the "biomass-to-energy" conversion process.

N.N. Mustafi , Y.C. Miraglia , R.R. Raine , P.K. Bansal , S.T. Elder [8] represents alternate fuel for internal combustion engine. The primary objective of this study was to introduce the new synthetic gaseous fuel 'Powergas' to a spark ignition engine and to observe the effects of the fuel on the engine performance and emissions compared to the fuels gasoline and natural gas. The secondary objective was to employ a computer simulation of spark ignition engines to model the effects of the fuel composition on engine performance and emissions. 'Powergas' gives a lower power output than gasoline and natural gas fuels. Higher CO2 but lower CO concentrations in exhaust in the case of 'Powergas' operation. Much higher NOx emissions for 'Powergas' operation and the peak occurs at the very lean side of the stoichiometric (At $ø = 0.71–0.74$)

Stefanos Tsiakmakis, Dimitrios Mertzis, Athanasios Dimaratos, Zisimos Toumasatos, Zissis Samaras [9] represents spark-ignition engines running on gaseous fuels are commonly used for combined heat and power (CHP) production. In the present work, an experimental investigation has been conducted in order to study combustion in a spark-ignition engine fueled with producer gas. Three biomass feedstocks were evaluated, which are olive, peach and grape kernels. Mixtures of each producer gas separately with propane at various blending ratios were fed to the engine, operating at various engine speeds. Producer gas from every feedstock has much lower calorific value than propane (the baseline in the present work), due to the presence of inert gases (N2 and CO2). Lower cylinder pressures and heat release rates are observed for every producer gas compared to neat propane operation. The resulting power loss is attributed to the lower calorific value of producer gas. However, the reduction in power output does not exceed 10% for mixtures of 55% w/w producer gas and 45% w/w propane. Heat release rate profiles are wider for every producer gas, compared to neat propane, indicating slower flame propagation in the combustion chamber. Combustion stability is moderately affected by the introduction of producer gas in the combustible mixture.

G. Sridhar, P.J. Paul, H.S. Mukunda [10] represents the use of producer gas in reciprocating engines at high compression ratio (17 : 1), which hitherto had been restricted to lower compression ratio (up to 12 : 1). The current work clearly indicates the breakdown of this compression ratio barrier and it is shown that the engine runs smoothly at compression ratio of 17: 1 without any tendency of auto-ignition. Experiments have been conducted on multi-cylinder spark ignition engine modified from a production diesel engine at varying compression ratios from 11.5: 1 to 17: 1 by retaining the combustion chamber design. Performance of the engine at higher CR has been smooth and it has been established beyond doubt that the operating engines using producer gas in SI mode at higher compression ratios is technically feasible. The cylinder pressure–crank angle trace has shown smooth pressure variations during the entire combustion process without any sign of abnormal pressure raise. The maximum de-rating in power is observed to be 16% in gas mode when compared to diesel operation at comparable CR. Reduction in 10% heat loss to the coolant would amount to improvement in overall efficiencies by 3%.

V.S. Yaliwal, N.R.Banapurmath, N.M.Gireesh, P.G.Tewari [11] represents alternative fuel shave numerous advantages compared to fossil fuels as they are renewable and biodegradable besides providing energy security and foreign exchange saving addressing environmental concerns, and socio economic issues as well. In view of this exhaustive experiments on the use of producer gas for both spark ignition (SI) and compression ignition (CI) engine applications for short and long term trial runs have been reported in the literature. This paper mainly presents a literature review based on the utilization of producer gas as fuel for transport and power generation applications. Producer gas derived from biomass can be used as a sole fuel for SI engine and as a supplementary fuel for CI engines in dual fuel mode.

Uisung lee, elango balu, j.n.chung [12] presents the feasibility study of a sound scientific, engineering, and technological solution for converting biomass to electrical power using a downdraft biomass gasification system coupled with a spark-ignited IC engine/electric generator set for portable power applications on agricultural farms and in rural areas. The main objective of this study is to investigate the coupling and integration between the gasification unit and the power generation unit. A downdraft gasification unit was successfully coupled with a conventional spark ignition IC engine without any special modification. The thermodynamic efficiencies for the gasifier were found in the range of 81.7–84.6%. The engine efficiencies fall in the range of 25.6–29.5% for horse manure, red oak and pine with only 20.3% for the cardboard. On the overall system performance, the integrated efficiencies were determined at 20.6%, 21.3% and 23.0% for red oak, horse manure and pine, respectively. Again, the cardboard delivered the lowest overall system efficiency at 15.8%.

Pratik N. Sheth, B.V. Babu [13] perform on a downdraft biomass gasifier is used to carry out the gasification experiments with the waste generated while making furniture in the carpentry section of the institute's workshop. Dalbergia sisoo, generally known as sesame wood or rose wood is mainly used in the furniture and wastage of the same is used as a biomass material in the present gasification studies. The effects of air flow rate and moisture content on biomass consumption rate and quality of the producer gas generated are studied by performing experiments. Based on the results of this study, the conclusions drawn are with an increase in the moisture content, biomass consumption rate decreases and with an increase in the air flow rate biomass consumption rate increases, The calorific value, pyrolysis zone temperature and the oxidation zone temperature are maximum at equivalence ratio ø = 0.205. However, the calorific value decreases for an equivalence ratio ranging from 0.205 to 0.350, with an increase in ø, the production rate of producer gas continuously increases.

A.S. Ramadhas , S. Jayaraj, C. Muraleedharan [14] represents the potential of coir-pith and wood chips as the feedstock for gasifier is analyzed. The performance of the gasifier–engine system is analyzed by running the engine for various producer gas–air flow ratios and at different load conditions. The performance and emission characteristics of the dual fuel engine are compared with that of diesel engine at different load conditions. It can be seen in that the brake thermal efficiency of the dual fueled engine is lower than that of diesel. The maximum brake thermal efficiency of 25% is achieved in diesel mode. In the dual fuel mode of operation, the maximum brake thermal efficiency was of 19.9% at 70% load using coir-pith and 21% at 70% load using wood chips. The specific energy consumption of the engine is higher at part load conditions irrespective of the fuel used Specific energy consumption in dual fuel mode is higher than that of diesel mode at all load conditions. The engine performance decreases in dual mode operation with diesel or rubber seed oil as pilot fuel. The pilot fuel consumption of rubber seed oil is higher than that of diesel in dual fuel mode operation. Carbon monoxide emission of rubber seed oil-producer gas operation is higher than diesel-producer gas operation under all load conditions because of higher fuel consumption with lower calorific value fuels. Moreover, higher carbon dioxide emissions are observed with rubber oil-producer gas operation. The exhaust emissions are found to be closer irrespective of the fuel used. The power generation cost while using biomass is much cheaper than the conventional power generation cost.

N.R. Banapurmath, P.G. Tewari [15] studied on honge oil and its methyl ester. They used dual fuel mode engine. To evaluate and compare the performance of a direct injection (DI) CI engine operated on dual fuel mode with and without gas carburetor; to check the feasibility of popular alternative fuels in the form of Honge oil and its methyl ester and producer gas as a total replacement for fossil fuels. In view of this, Honge oil (Pongamia Pinnata Linn) is selected and its viscosity is reduced by the transesterification process to obtain Honge oil methyl ester (HOME). Since vegetable oils produce higher smoke emissions, dual fuel operation could be adopted in order to improve their performance. The brake thermal efficiency values of 24.25%, 22.25% and 23% were obtained with producer gas–diesel, producer gas–Honge oil and producer gas–Honge oil methyl ester, respectively. With dual fuel operation emissions such as smoke and NOx were reduced considerably. However, CO and HC emissions increased considerably.

P.C. Roy, A. Datta N. Chakraborty [16] presents a performance analysis of downdraft biomass gasifier has been done using an equilibrium model for the pyro-oxidation zone and kinetic model for the reduction zone. The study has been carried out with three woody biomass (rubber wood, eucalyptus wood and bamboo wood), two agricultural wastes (wheat straw and rice straw) and coconut shell. Finally, an economic analysis based on fuel price is made for the corresponding operating conditions of all the fuels. It is found that wheat straw gives the maximum bio-energy generation rate and the minimum specific fuel cost (Rs. /MJ of energy) among the fuels compared. It is considered that the gasifier should operate with critical char bed length in the reduction zone irrespective of the fuel that is used. The gas production rate and pressure drop across the gasifier should also be maintained the same with every fuel so that the blower, which is driving the gas from the gasifier to the engine downstream, can function at its rated condition. With every fuel, the feeding rate, equivalence ratio and feed particle size should be properly chosen to achieve the above goals. The equivalence ratio is chosen to yield the critical char bed length in the gasifier reduction zone. The producer gas flow rate should be controlled by the feed rate of the biomass fuel. However, a change in the biomass fuels alters the heating value of the producer gas and the bio-energy generation rate due to gasification.

Mohammad Asadullah [17] present gasification is one of the promising technologies to convert biomass to gaseous fuels power generation. In this review, the barriers in each of the steps from the collection of biomass to electricity generation are highlighted. The effects of parameters in supply chain management, pretreatment and conversion of biomass to gas, and cleaning and utilization of gas for power generation are discussed. According to the recent paper, an advanced gasification method with efficient tar cleaning can significantly reduce the biomass consumption, and thus the logistics and biomass pretreatment problems can be ultimately reduced. To overcome the logistic problem sand to meet the power requirement at the remote areas, the distributed power generation at the location where biomass is abundant could be more economic. In order to reduce the technical problems, a small size (1–10MW) of the plant could be suggested. The mixed gasifying agent, for instance, air and steam, could provide suitable gas composition for gas engines with higher thermal efficiency.

P. Raman, N.K. Ram, Ruchi Gupta [18] perform on a dual fired downdraft gasifier system was designed to produce clean gas from biomass fuel, used for electricity generation. This system is proposed to overcome a number of technical challenges. The system is equipped with dry gas cleaning and indirect gas cooling equipment. With the improved gasifier system, the tar level in the raw gas is less than 100 mgNm-3. Cold gas efficiency has improved to 89%. The improved dual fired gasifier system produces the gas with very low tar content, which is 67 mgNm-3 against 711 mgNm-3 of the reactor. This improved system produces the gas with very low dust content, which is 53 mgNm-3 against 1360 mgNm-3 at the exit of the reactor. At the exit of the gas cleaning train the tar content level is 35 mgNm-3 and dust content is nil. The calorific value of the gas is 5.3 MJNm-3. The specific gasification rate is 2.8 Nm-3 of producer gas per kg of fuel wood. The cold gas efficiency of the improved gasifier system is 89.7%. The specific fuel consumption is 1.1 kg of fuel wood per kWh against the normal value of 1.5-1.6 kg kWh-1. Biomass to electric conversion efficiency of the system is found to be as 21%.

P. Raman, N.K. Ram [19] represents the design and development of biomass gasifier. The objective of the research work, reported in this paper is, to design and develop a downdraft gasifier based power generation system of 75 KW. A detailed analysis of the mass, energy and elemental balance is presented in the paper. The cold gas efficiency of the system is increased from 75.0% to 88.4%, due to the improvements made in the ash removal method. The Specific Fuel Consumption (SFC) rate of the system is 1.18 kg kWh-1. The energy conversion efficiency of the system, from fuel wood to electric power was found to be 18%.The biomass gasifier based power generation system was continuously operated and monitored during the experiment. The system was operated with a maximum load of 73 kW and a minimum load of 65 kW. With an ER of 0.35, the calorific value of the producer gas was 5.7 MJ Nm-3. The improved ash removal system and hot air injection contribute to minimize the specific fuel (wood) consumption to 1.18 kg kWh-1. The energy conversion efficiency of producer gas to electric power was worked out to be 21%. The electrical power output was remained closer to 73 kW. The energy balance analysis indicates that 88.4% (energy fraction percentage) of the energy from the fuel wood was converted into producer gas.

III. CONCLUSION

From literature survey, different findings are concluded:

- Different types of feed stocks are available with different characteristics of gases having different properties.
- Biomass gasification offers the most attractive alternative energy system for agricultural purposes.
- If we change parameters of design of gasifier we can improve the purity of gas with low tar content.
- The dual fuel mode engine has lower thermal efficiency than diesel engine.
- We save diesel with dual fuel mode (producer gas + diesel).
- A de-rating of 30-50 % was found in most of the research papers.
- Hence, it is necessary to develop a dedicated producer gas engine technology.

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