Renewable and Sustainable Fuels for Rural Energy Applications

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ABSTRACT

Energy is the lifeline of modern societies. Recognizing the energy needs of the rural population, India has launched several programmes on biomass gasifier based power units with as high as MW level grid connected plants that operate on dual fuel and 100% producer gas run engines. In this context, use of renewable fuels for power generation system seems to be more appropriate and need to explore this potential, feasibility and environmental implications of gasifier-engine system used for shaft power for rural applications is necessary. In the present work, experimental investigations were carried out on single cylinder four stroke direct injection stationary diesel engine operating on dual fuel mode using Honge oil methyl ester (HOME), bioethanol and producer gas combinations to determine its performance, and emission characteristics. 5 percent bioethanol was added to HOME (BE5) to study its effect on the dual fuel engine performance. HOME + 5% bioethanol-producer gas operation resulted in marginally comparative engine performance to diesel-producer gas operation. Emissions such as smoke, HC, CO levels were also lowered with bioethanol addition.

Keywords: Gasifier-engine system, performance, emissions, Honge oil methyl ester, Babul wood.

1. INTRODUCTION

Utilization of producer gas in diesel engines has both economic and environmental advantages. The economic benefit stems from the availability of producer gas in large quantities in many parts of India. The use of the gaseous fuel locally would save the use of liquid fuels. Renewable and alternative fuels have numerous advantages compared to fossil fuels as they are renewable, biodegradable; provide energy security and foreign exchange saving besides addressing environmental concerns and socio-economic issues as well. In this context, use of renewable fuels for power generation system seems to be more appropriate and need to explore this potential, feasibility and environmental implications of gasifier-engine system used for shaft power for both rural and urban applications is necessary. Replacement of petroleum products, by such renewable fuels is indigenous and hence such an energy source has gained significant attention. A biomass gasifier-engine system used for electricity generation system is one of the feasible options for many villages existing in India.

Need for sustaining economic development is crucial for India and rest of the world. India has huge potential for biomass and agricultural residues and it is estimated that around 620 million tonnes of biomass reserves were available in the country during 2004-2005 and total biomass reserve was more than 700 million tonnes during 2010-2011. It is expected to be 1127 million tonnes during 2024-2025. Due to shortage in crude oil supply, India is still dependent on non-commercial fuel sources. At present, it is estimated that India will be able to produce 288 metric tonnes of biodiesel by the end of 2012, which will supplement about 41.14% of the total demand of diesel fuel consumption. In view of this, renewable energy is considered as one of the most promising alternatives. It is well released that decentralized and renewable energy-based options to meet the rural energy needs in a sustainable way. Among all the renewable energy sources, biomass is the largest, most diverse and readily exploitable resource.

In India, amongst the bioenergy technologies, the biomass based gasifier-engine system for meeting both rural and urban electricity needs is shown to have a large potential (Ravindranath et al 2004). Biofuels from non-edible oils and waste biomass do not compete with food and have high value for use in communities and leads to sustainable development. Hence, to achieve sustainable development, harnessing bioenergy through dual fuel technology is given with considerable interest because of its advantages. (Dasappa and Sridhar 2011, Banapurmath 2009, 2011; Yaliwal et al 2013). Numerous literatures were published on the use of biodiesel and producer gas (Banapurmath et al. 2007, 2009, Muralidharan and Vasudevan, 2011).

The brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and emission levels were considerably improved with increase in compression ratio (Banapurmath et al. 2011; Muralidharan and Vasudevan 2011). Many investigators have extensively studied gasifier – engine systems for both rural and urban power applications (Banapurmath et al. 2008, 2009, 2011; Cenk and Gumus 2011; Muralidharan and Vasudevan, 2011; Nouni et al. 2007; Ravindranath and Balachandra et al. 2009).

In the present work, major attention is given to enhance the power output of producer gas fueled dual fuel engine. In this context, experiments have been conducted on a water-cooled single-cylinder direct injection (DI) CI engine operated on dual fuel mode using HOME and producer gas, and with and without bio-ethanol addition. Also, results were compared with base line data generated.

2. CHARACTERIZATION OF HOME AND PRODUCER GAS

In the present study diesel and HOME was used as an injected liquid fuels and the producer gas is derived from Babul wood used as an inducted gaseous fuel and their properties are listed in Table1. Table 2 gives the typical composition of producer gas obtained from gasification on volumetric basis. The properties of producer gas derived from Babul wood are also presented in the Table 1.

3. EXPERIMENTAL SETUP

Experiments were conducted on a Kirloskar TV1 type, four stroke, single cylinder, water-cooled diesel engine test rig. Figure 1 shows the schematic experimental set up. Eddy current dynamometer was used for loading the engine. The fuel flow rate was measured on the volumetric basis using a burette and stopwatch also. The engine was operated at a rated constant speed of 1500 rev/min

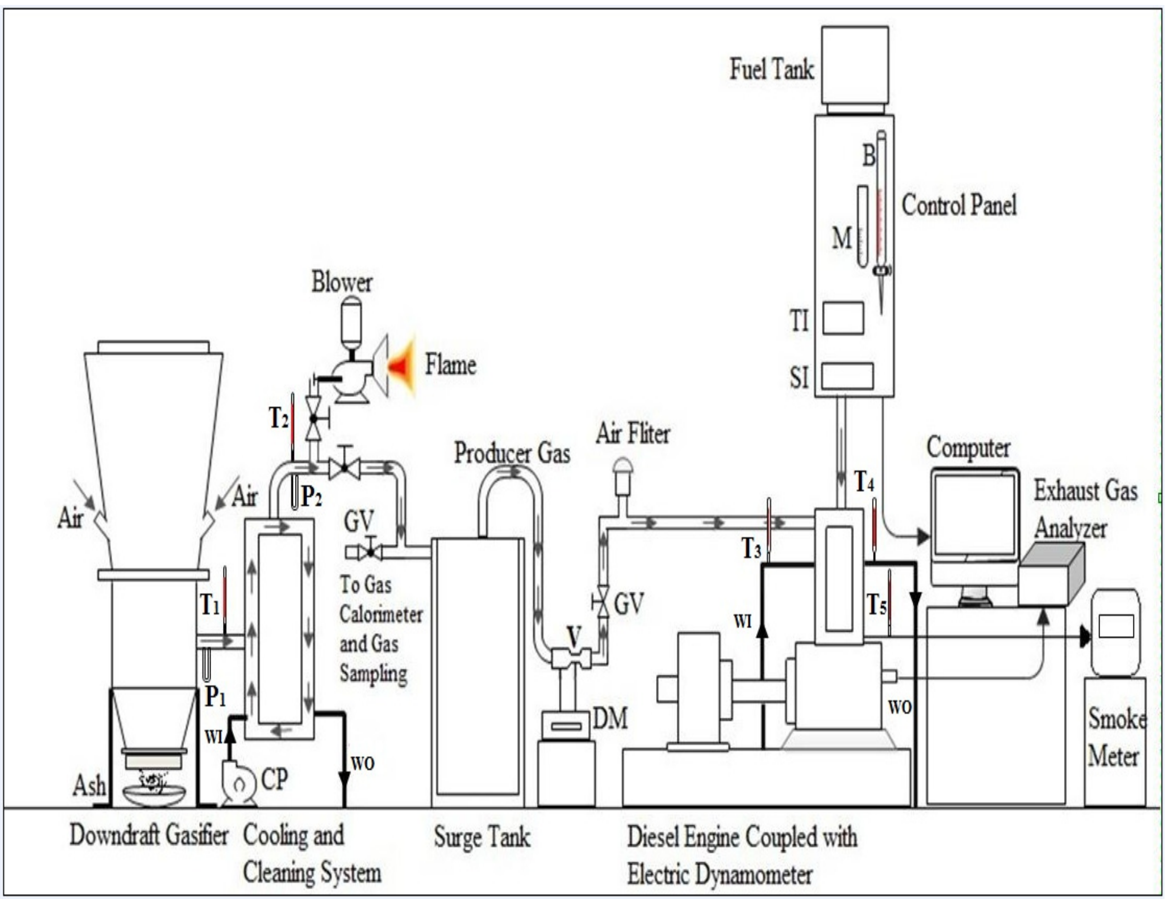

Figure 1 Experimental set up

The down draft gasifier was suitably connected to the engine with filter and cooling and cleaning system. The Engine soft is software, evaluates power, efficiencies, and fuel consumption and heat release and pressure – crank angle diagram. The emission characteristics were measured by using HARTRIDGE smoke meter and AVL make equipment during the steady state operation. The tests were conducted with HOME – producer gas combination with and without bioethanol addition and compared with diesel –producer gas operation. The specification of the compression ignition (CI) engine and down draft gasifier was given in Table 3.

Table 1: **Properties of fuels tested**

Sl No	Properties	Diesel	HOME	Babul Wood	Compos-ition
1	Viscosity @ 40 ^{0} C (cst)	4.59 (Low)	5.6	Moisture Content, % wlw	11.9
2	Flash point ^{0}C	56	163	Ash Content, % wlw	0.79
3	Calorific Value in kJ / kg	45000	36, 010	Volatile Matter, % wlw	85.8
4	Specific gravity	0.830	0.870	Fixed Carbon % w/w	13.4
5	Density Kg / m3	830	890	Sulphur, % wlw	0.05
8	Type of oil	----	Non edible	Nitrogen, as N % wlw	0.25
9	------	----	------	Calorific value MJ/kg, and Density, kg/ m^3	17.5 and 288

Table 2 Composition of producer gas

Constituents in percentage						
Type of wood	CO_2	H_2	CH_4	H/C	N_2	Water Vapour
Babul wood	18-22%	15-19%	1-5%	0.2-0.4%	4.5-5.5%	4%

Table 3: Specification of CI Engine

Sl No	Diesel engine		Down draft gasifer	
	Parameters	Specification	Parameters	Down draft gasifier
1	Type of engine	Kirlosker Single cylinder four stroke direct injection diesel engine	Supplier	Ankur Sci. Energy Tech. Pvt. Ltd., Baroda.
2	Nozzle opening pressure	200 to 205 bar	Rated capacity and gas flow	62735 kJ/h and 15 Nm^3/h
3	Rated power	5.2 KW (7 HP) @1500 RPM	Average gas calorific value	5-5.6 J/m^3
4	Cylinder diameter (Bore)	87.5 mm	Rated woody biomass consumption	5-6 kg/h
5	Stroke length	110 mm	Hopper storage capacity	40 kg
6	Compression ratio	17.5 : 1	Typical conversion efficiency	70-75%

4. RESULTS AND DISCUSSIONS

This work involves the performance evaluation of HOME-producer gas dual fuel engine operation. The present work compares performance of the HOME-bioethanol-producer gas operation with HOME-producer gas and diesel-Producer gas operation. The tests were conducted with different load conditions. Maximum bioethanol proportion was limited to 5% (by vol). During the complete experimentation, engine speed was maintained constant. The injection timing, injection pressure and compression ratio were kept constant at 27^0 bTDC, 230 bar and 17.5 respectively. However, for Diesel–Producer gas operation, injection pressure was changed to 205 bar. Babul wood was used as a fuel for gasifier and parallel flow (90 degree) gas entry carburetor was used to ensure air-gas mixture at stoichiometric ratio.

4.1 Performance Characteristics

The variation of brake thermal efficiency (BTE) with a brake power is shown in Figure 2. The BTE of HOME- producer gas dual fuel engine increases with 5%bioethanol addition. This is because increased volatility of fuel combination. It leads to higher flame temperature and due to which better combustion was resulted. However, BE10–producer gas operation resulted in lower BTE compared to BE5–producer gas combination. This could be attributed to the combined effect of reduced energy content of HOME, bioethanol and producer gas combination. Higher latent heat of vaporization of bioethanol leads to cooling effect, and difference in fuel's input chemical availability may be the reason for this trend.

4.2 Emission Characteristics

Figure 3 shows that BE5-producer gas shows decreased smoke emission levels. Adding 5% bioetahnol in base liquid fuel (HOME) increases volatility of HOME leading to increased combustion temperature and pressure resulting in better oxidation of fuel combination hence better combustion, there by flame produced by burning of fuels used reaches the entire area of cylinder. Hence lower smoke emission levels were obtained at BE5-producer gas combination compared to other fuel combinations.

Figure 4 and 5 shows adding 5% bioethanol in HOME decreases the HC and CO emission levels compared to other fuel combinations. It could be due to increased volatility improves better mixing of fuel combinations and increases the combustion temperature and pressures resulting in better oxidation hence better combustion.

The higher BTE at BE5-producer gas combination is also responsible for this trend as well. In general, dual fuel operation with HOME – producer gas operation leads to higher HC and CO emission levels compared to diesel –producer gas operation. This is because producer gas contained CO as a main constituent and also the producer gas has lower flame velocity. This may require more time to ensure the complete combustion. The mixture of producer gas and HOME biodiesel results in to incomplete combustion. This in turn generates higher CO and HC through exhaust.

The variation nitric oxide (NOx) emission with brake power is shown in Figure 6. The NOx emission levels with HOME-producer gas combination dual fuel operation are lower compared to BE5-producer gas and diesel-producer gas operation. This is because the combustion temperature inside the engine cylinder is lower with HOME-producer gas combination and also due to the lower calorific value of HOME and producer gas combination is responsible for this trend. Another reason for this trend is due to incomplete combustion resulting lower combustion temperature. BE5-producer gas results in to increased NOx emission levels compared to HOME-producer gas combination. This may be attributed to increased combustion temperature due to the use of bioethanol addition.

4.3 Fuel substitution

Figure 7 shows the fuel substitution for dual fuel operation with various fuel combinations. The maximum fuel substitution is given prime importance in dual fuel mode of operation and it depends on injected fuel's physico-chemical properties of the supplementary fuel such as cetane number, viscosity and calorific value and basic engine design. Fuel substitution values were higher for BE5 –producer gas combination. The bioethanol addition improves brake thermal efficiency and hence allowing more producer gas burning to produce the same power output. The percentage of fuel substituted with diesel -producer gas, HOME- producer gas and BE5-producer gas combination were reported as 60.05, 55.1 and 56 % respectively.

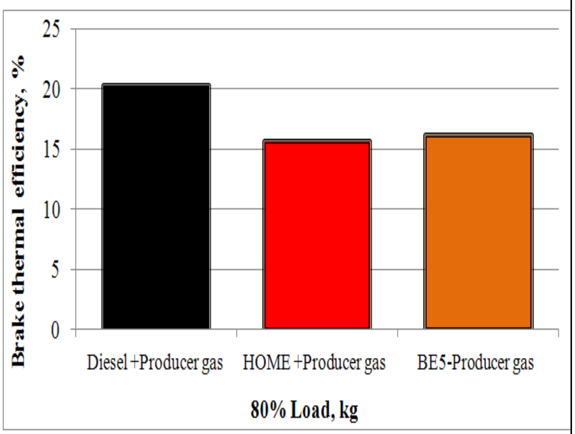

Fig. 2 variation of BTE with brake power

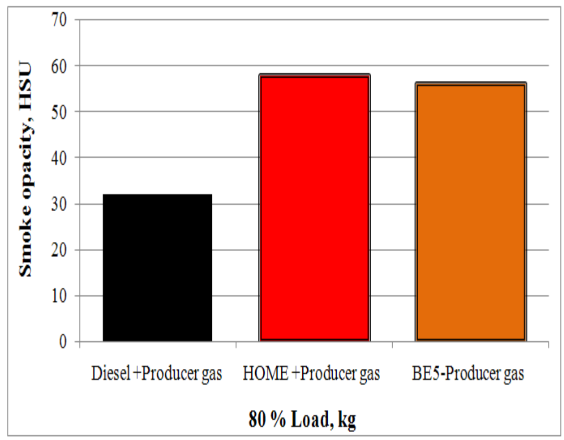

Fig. 3 variation of smoke with brake power

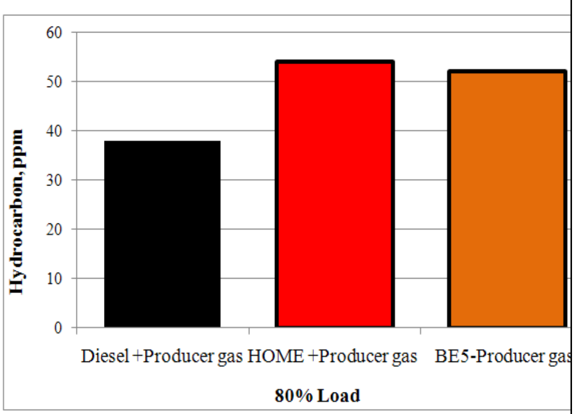

Fig 4 Variation of HC with brake power

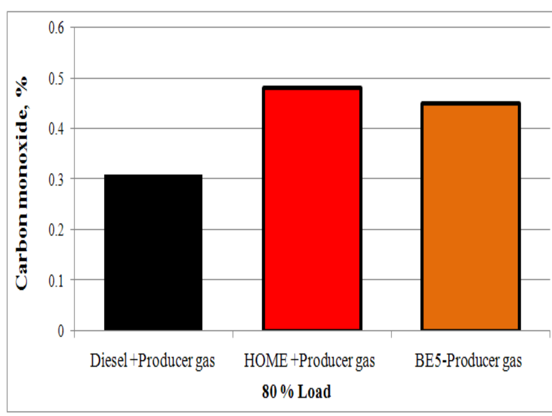

Fig 5 Variation of CO with brake power

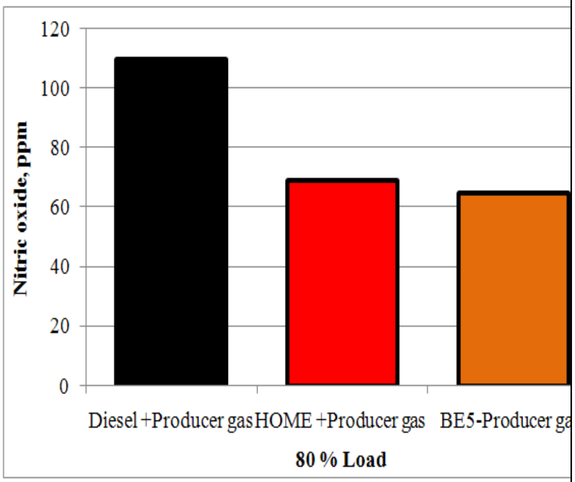

Fig. 6 Variation of NOx with brake power

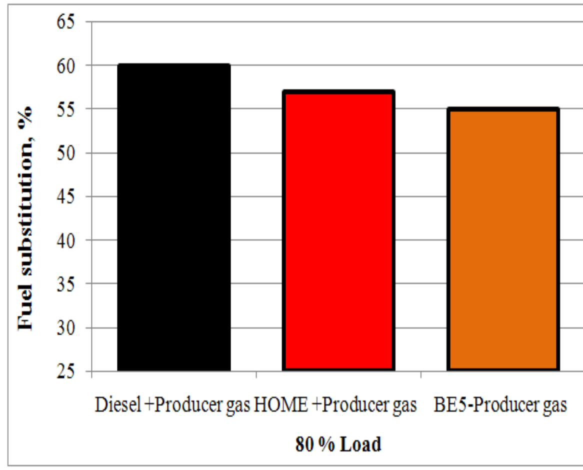

Fig. 7 Fuel substituted with brake power

5. CONCLUSIONS

Some important findings on the engine performance and environmental aspects in dual fuel mode of operation while using producer gas derived from Babul wood and HOME and bioethanol blend as an injected fuel are highlighted in the present paper and following conclusions are made from the present study.

- The HOME or bio-diesels can be used in dual fuel mode with producer gas induction and this feature does not require any major engine modifications.
- The maximum brake thermal efficiency for BE5 – producer combination was found to be 16.25% compared to 15.65% for HOME-producer gas operation. The emissions such as HC and CO are reduced to lower extent with bioethanol additioon compared to the operation with HOME-producer gas combination. The power de-rating in producer gas operated dual fuel engine is of the order of 20%. The power output of the engine used is 3.7 kW and the engine is operated at less than 80% of the load.
- The above study showed that Babul wood was an excellent feedstock for gasification. The maximum diesel replacement obtained was 59.65% at 80 % load.

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