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Engine Performance and Emission Characteristics of a Single Cylinder Four Stroke CI Engine on Dual Fuel Mode by Using Compressed Biogas as a Fuel

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Abstract: Conventional fuels like diesel and petrol are depleting day by day, so we have to search for an alternative fuel. The aim of study is to analyze the performance and emission characteristics existing single cylinder four stroke compression ignition (CI) engine converted into dual fuel mode. In the present studies the effect of Biogas on the performance diesel engine on dual fuel mode. Biogas used as primary fuel and Diesel used as secondary (pilot) fuel on dual fuel mode, Dual fuel mode is one of the better methods to control emissions from CI engines and instantaneously replacing existing diesel fuel engine. Experiments is carried out under engine laboratory condition, analyze the performance and emission characteristics of single cylinder CI engine on dual fuel mode by using Biogas used as fuel by varying the Biogas percentage. The reduction in CO and HC emissions on dual fuel mode for different loads were observed.

Keywords: Biogas, Diesel engine, Dual fuel mode, Vacuum vaporizer, Exhaust emission.

I. INTRODUCTION

Due to the rapid depletion, increasing prices, increasing demand of petroleum fuel, fuels which are renewable, clean burning as substitute fuel for IC engine. Diesel fuel is widely used in transportation sector and agriculture sectors and biogas is biodegradable, non-toxic and economical. Existing diesel engine converted into dual fuel mode it reduce the engine emission because now days emission norms mainly consider along engine performance. An alternative fuel like biodiesel, biogas, CNG, LNG, LPG, hydrogen gas, producer gas, ethanol, etc. Among all various gaseous fuels, Biogas is economical among these fuel. Biogas is generated from cow manure, Municipal Organic Solid Wastes (MSOW) by anaerobic digestion. Biogas consists of methane about 60 to 70%, and 20-30% carbon dioxide (CO_2), 5-8% hydrogen and small amounts of other gases like O_2 and N_2. Biogas is used as alternative fuel or substitution fuel for IC engines. It may contain some scums in small amounts like hydrogen sulphate (H_2S) and vapor particle (H_2O). The composition of Biogas shown in Figure 1-1.

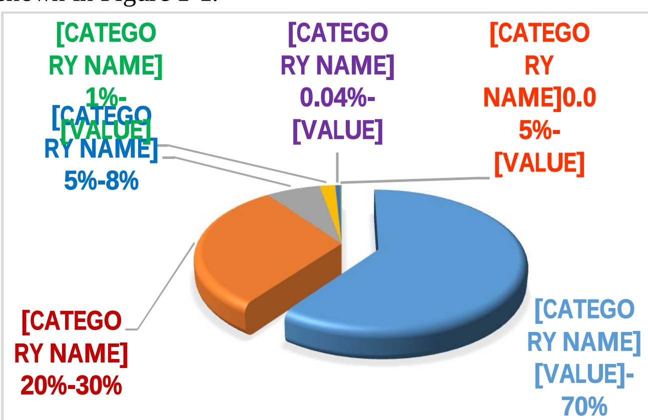

Figure I-1: Biogas Composition

II. MATERIAL AND METHODS

Convection diesel engines with minor modification were made to operate on gaseous fuels by using Gas mixer fixed at line of intake air for efficient burning of gases fuel in combustion chamber, pilot fuel is required for start an engine at high CR these type engine is called dual fuel engine. Such engines usually have the gaseous fuel mixed with the air in the mixing chamber (gas mixer) and then rushes into the engine cylinders, which is ignited at the final stage of the compression stroke by a liquid fuel injection (pilot fuel) with good ignition properties. Induction of biogas fuel is called primary fuel and diesel fuel used as pilot fuel. Reduction of engine emission when biogas used as gases fuel on dual fuel mode.

A. Fuel Properties

The properties of Diesel and Biogas fuel as shown in Table 2-1.

Table II-1: Properties of fuels

Properties	Diesel	**Biogas**
Density kg/m^3	830	0.69
Kinematic Viscosity at ASTM std. 40^{0}C cSt (mm^2/s)	3.98	-
Flash point ^{0}C	49	-
Fire point ^{0}C	55	-
Calorific value kJ/kg	42382.4	37000

B. Experimental Test Set Up

A single cylinder four stroke water cooled diesel engine installed at laboratory. Converted diesel engine into dual fuel mode by attaching venturi gas mixer to intake manifold. Four pass venturi gas mixer is designed and fabricated according to engine specification, gases fuel and intake air mixes in gas mixer then rushes to cylinder through intake valve. Biogas used as fuel and Diesel used as a pilot fuel. Test conducted at injection timing 23^{0}bTDC with 210 bar pressure and the engine was operated at 1500 rpm, under naturally aspirated conditions. Test set up instruments were used which included test engine, conversion kit, dynamometer, air box with orifice meter and manometer, venturi gas mixer, Biogas cylinder, pressure sensor, speed encoder, temperature sensor, Electrical loading, load sensor, engine performance analysis software(engine soft), exhaust gas analyzer, etc. Schematic layout of experimental setup as shown in Figure II-1:

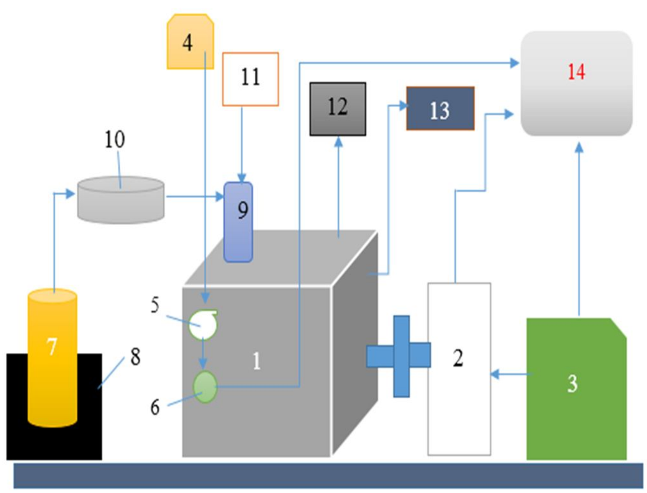

Figure II-2: Schematic layout of four stroke single cylinder Diesel engine on duel fuel mode

1. Diesel Engine.

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2. Alternator.
3. Electrical loading.
4. Fuel tank.
5. Fuel injector.
6. Pressure Sensor.
7. Biogas Cylinder.
8. Weighing machine.
9. Gas mixer/Mixing chamber.
10. Vacuum vaporizer.
11. Air box.
12. Exhaust temperature Measurement meter.
13. Exhaust gas analyzer.
14. Data stored in Computer.

Figure 2-2. Shows an experimental setup of four stroke single cylinder Diesel engine on duel fuel mode.

Table II-2: Engine Specification

Company	Kirloskar
Engine type	4 Stroke Single Cylinder
Power	5.2 KW
Bore	87.5 mm
Stroke	110 mm
Cooling	Water Cooled
Speed	1500 rpm
Compression Ratio	17.5:1
Fuel injection	Mechanical Injection with injection timing 23^0 BTDC, 210bar injection pressure.

Kirloskar engine specification is shown in Table 2-2.

Figure II-3: Computerized, Electrical loading single cylinder four stroke CI engine converted to Dual fuel mode with compressed Biogas used as a fuel

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III. RESULTS AND DISCUSSIONS

The results obtained by performing experiments under pure diesel mode and dual fuel mode and results are shown in figures.

A. *Engine Performance*

Variation of performance parameters at injection timings 23^0 bTDC, 210 bar pressure, speed 1500 rpm with brake power of 0.588 kW, 1.176 kW, 1.765 kW, 2.353 kW, 2.941 kW, 3.5294 kW and 4.118 kW.

1) Brake Thermal Efficiency:

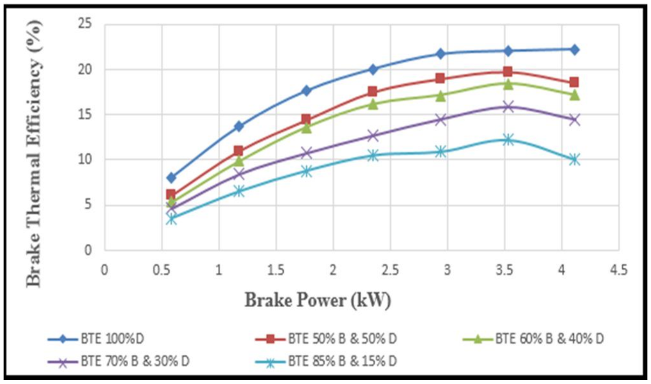

Figure III-1: Variation of BTE with BP for the varying Biogas percentage

The variation of BTE with BP for changing the biogas percentage is shown in Figure 3-1. Replaced diesel fuel with Biogas up to 85% with smooth running operation. As a BP increase BTE also increase up to part load condition at full load condition decreases due to maximum amount of fuel consumption at full load conditions. As a biogas percentage increase BTE decreases because biogas have less calorific value that is 37000 kJ/kg. At 85%diesel replace maximum BTE achieved that is 12.22%.

2) Specific Fuel Consumption:

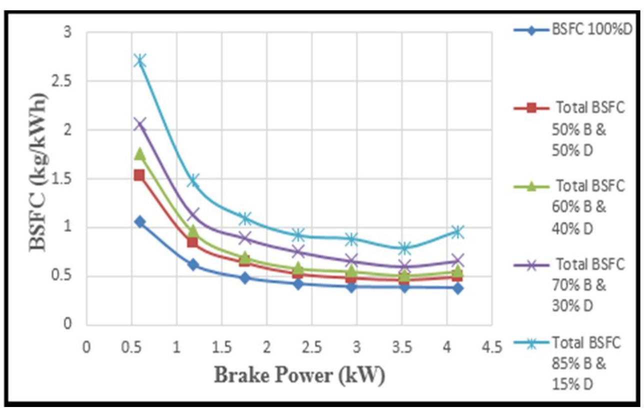

Figure III-2: Variation of BSFC with BP for the varying Biogas percentage

The variation of BSFC with BP for changing the biogas percentage is shown in Figure 3-2. As Diesel substitution increase with increase in BSFC along the BP, maximum BSFC occur at 0.588kW is 2.73 kg/kWh. Specific Fuel Consumption was calculated by fuel consumption divided by the rated power output of the engine. Brake Specific Fuel Consumption for diesel with Biogas fuel is calculated at different loads. The engine fuel consumption depends on speeds, load and different injection timing. It can be seen that BSFC is decreased with increasing brake power due to high percentage of conversion of heat energy into useful work. The translation of heat energy to mechanical work increases with rise in combustion temperature and that leads decrease of BSFC with respect to load. And it is also observed that the BSFC has decreased by increasing with retarding injection timing. The lowest BSFC is obtained at 100% Diesel fuel.

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B. Emission characteristics

1) Carbon Monoxide (CO) Emission

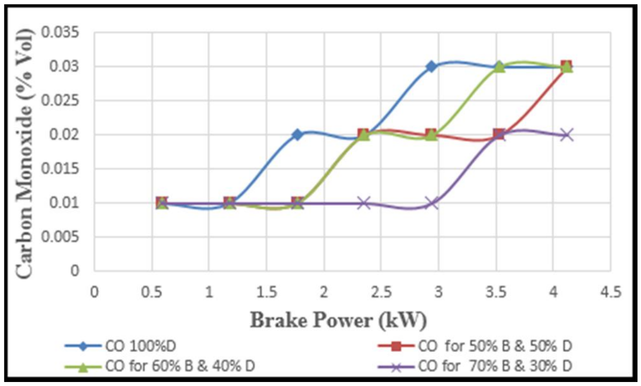

Figure III-3: Variation of CO emission with BP for the varying Biogas percentage

The variation of carbon monoxide with brake power at different injection timing for different fuels as shown in Figure 3-3. As we observed that CO emission increases with load and emission reduces due biogas mixes with diesel fuels. Therefore, emission of CO is greatly dependent on the air to the fuel ratio. Rich combustion consistently produces CO. The reduction of CO emission occurred when increasing percentage substitution of biogas over diesel fuel. Burning property of Methane gas is higher than the Diesel fuel, Biogas cylinder contains 86% of Methane gas.

2) Hydrocarbon (HC) Emission

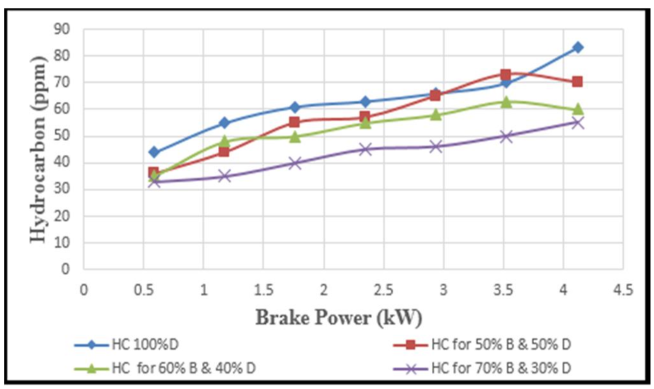

Figure III-4: Variation of HC emission with BP for the varying Biogas percentage

The variation of hydrocarbon emission with brake power for different fuels composition as shown in Figure 3-4. Some amount of fuel do not react due to insufficient of O_2 and the combustion will be incomplete. Due to this higher the HC emission in the case liquid fuel compared to gases fuel. 70% of biogas substitution over diesel fuel give 30% reduction of HC emission at 0.533 kW BP and 50% reduction of HC emission at 4.11 kW BP.

3) Carbon Dioxide (CO_2) Emission

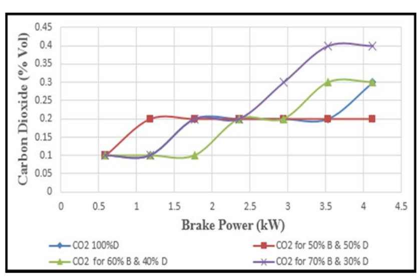

Figure III-5: Variation of CO2 emission with BP for the varying Biogas percentage

The variation of Carbon dioxide emission with brake power as shown in Figure 3-5. Combustion of a Hydrocarbon fuel produce

CO_2 and water. Fuel got sufficient amount of oxygen to react with hydrocarbon for CO_2 emission and at initial part load condition 100% diesel fuel give more CO_2 emission and at full load condition 70% biogas substitution give the maximum CO_2 emission.

4) Nitrogen Oxide (NO_X) Emission

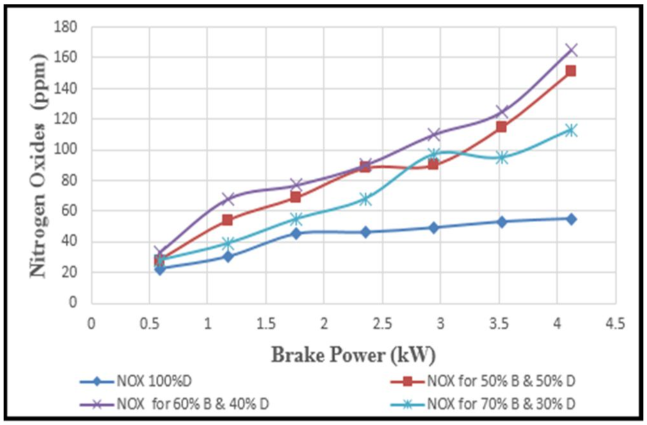

Figure III-6: Variation of NOX emission with BP for the varying Biogas percentage

The variation of NO_X emission with brake power as shown in Figure 3-6. Diesel fuel NO_X emission is less compared to Biogas fuel. Combustion of gases fuel is faster than the liquid fuel. Due to proper mixing of biogas and air in the mixing chamber (venturi gas mixer).

C. Peak Pressure Curve For Changing The Biogas Percentage

Peak Pressure curve shown for changing Biogas percentages with Diesel at injection timing 23^0 bTDC, pressure 210 bar and speed 1500 rpm.

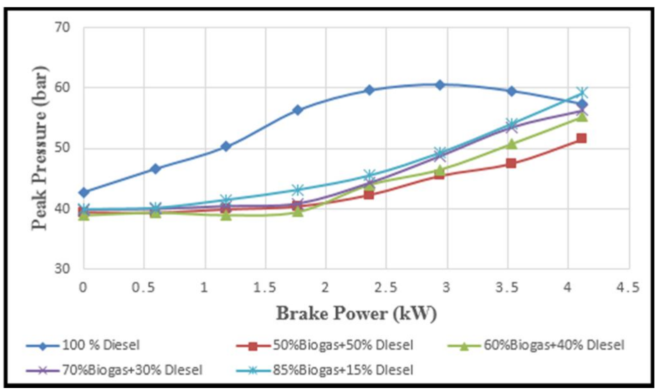

Figure III-7: Variation of Peak Pressure for varying the biogas percentage with BP

Variation of Peak Pressure with brake power shown in Figure 3-7. It is clearly seen that peak pressure increases with increasing BP. Maximum Peak pressure rise for 100% Diesel fuel. At no load peak pressure rise less than the full load due to delay period, pressure and temperature. Peak pressure rise is less at 50% of biogas substitution over diesel, as load increases peak pressure rises.

IV. CONCLUSION

From the results obtained, the fallowing conclusions are made.

Achieved 85% substitution of biogas fuel over diesel at Dual fuel mode.

Dual fuel operation is very effective method to reduce unburned hydrocarbons.

The maximum BTE obtained for CI engine on dual fuel mode 19.6% and less BSFC obtained at 50% biogas 50% diesel.

Best result is obtained for engine performance and emission characteristics is 60% biogas 40% diesel fuel.

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