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Evaluation Dual Fuel Engine Fuelled With Hydrogen and Biogas as Secondary Fuel

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Abstract -The present energy scenario hydrogen fuel plays a dominant role in the power generation. Due to its unique characteristics of an extensive range of flammability, high flame speed, and diffusivity. In this present investigation, the diesel engine is converted into dual-fuel mode devoid of major conversions of the engine. The tests are performed on a dual-fuel mode and investigated the efficiency, emissions, and combustion features of the diesel engine. In the present context, hydrogen and biogas are injected from the inlet manifold as subsidiary fuel and diesel are injected as pilot fuel. The gaseous fuel injected in two different flow rates they are, 3 litres per minute (lpm), and 4lpm. The results from the experimentation revealed that the diesel with 4 lpm of hydrogen shows the 31.11 % enhancement of brake thermal efficiency but it shows 4.14% higher NO_X emissions when compared with the pure diesel. But it shows. At the same time diesel with 4 lpm of Biogas exhibits 15.90% enhancement of brake thermal efficiency and 8.96% decrease in the NO_X emissions in contrast to that of the single-mode of fuel with diesel.

Keywords- dual fuel, hydrogen, biogas, emission, performance, combustion.

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I. INTRODUCTION

As we have seen in the past few years, there is a decline in the availability of crude oil, as well as prices, are also hiking [1]. So, there is a need to look at a new combination of fuels (i.e. alternative fuels) [2]. There are a number of alternative fuels such as Hydrogen, Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Alcohol, Biogas, Liquefied Natural Gas (LNG), Producer gas, vegetable oils, biodiesel, and emulsified biodiesel [3].

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Out of which hydrogen and biogas have been concentrated because of their dominance [4]. Dual fuel engine exhibit efficient performance when compared with single fuel mode of operation. Hydrogen exhibit wider flammability range and higher flame velocity and limited pollutions, so it becomes a common choice to use it as a subsidiary fuel in the dual-fuel engine [5]. Also, hydrogen properties are better than (compared to the) other gaseous fuels.

In addition, biogas has the potential to meet the increased energy demand in internal combustion engines. Biogas produces less output as compared to the natural gas; conversely, the application of biogas allows exhaust NO_X emissions to be condensed considerably. Biogas is made from organic fermented under the anaerobic condition.

Presently several researchers are carried out the investigation on dual-fuel engines by utilizing the different gaseous fuels. A.E. Dhole et al [6] worked on the dual-fuel engine by utilizing the hydrogen as a subsidiary fuel, from that they conclude the following points; dual-fuel mode enhances the brake thermal efficiency at critical load conditions. But it shows a reduction in brake thermal efficiency at low load conditions in support of all sets of diesel and producer gas combinations. The emissions like unburnt HC/CO were found to be lower and NO_X emission increases for all diesel and producer gas combinations. D.B. Lata et al. [7] observed that LPG and hydrogen as the subsidiary fuel to improve the brake thermal efficiency factor at the critical load condition. The emissions like un-burnt hydrocarbon, NO_X, in addition to the smoke were noticed to be considerably lower at higher load conditions in a combination of LPG and hydrogen as subsidiary fuels. Selvi Rajaram, P., et al. [8] carried out the investigation on the diesel engine, by using the Oxygen Enriched Hydrogen gas. From that they found, enhancement of brake thermal efficiency by 11.06%, CO emission decreased by 15.38%, CO_2 augmented considerably by 6.06%, NO_X emission augmented by 11.19% and the smoke content decreased significantly by 26.19%. Premkartikkumar et al., [9] Investigated that specific fuel consumption of hydrogen with diesel decreased at 8lpm and increased at the 21pm hydrogen flow rate, CO emission was decreased by 80%. Venkateswarlu Chintala et al. summarised that hydrogen in a dual-fuel in the engine increases the thermal competence at the higher as well as modest loads whereas considerably decreases at the lower load conditions, hydrocarbons, carbon dioxide, carbon monoxide, and the matter of smoke particulates substantially decreased in the dual-fuel mode.

NO_X was increased drastically at higher and modest load conditions may be attributed for the higher in-cylinder temperatures. Debabrata Barik et al., [10] investigated that the bio-gas rate of flow with 0.9kg/hr at a concentrated energy composition of range in between 30.1% and 58.4% show an optimal result with another flow rate in dual fuel operations in terms of efficiency, emission and combustions. Bhaskar J. Bora et al., [11] conducted the experiments on diesel-engine with the application of raw biogas as subsidiary fuel; they found that emissions like carbon monoxide (CO) and hydrocarbons significantly reduced by 26.22% and 41.97%, NO_X as well as CO_2 increased by 66.65% and 27.18%.

II. MATERIALS AND METHODS

A. Hydrogen

Hydrogen is a non-metallic element that is the simplest and lightest of the elements, is normally a colourless, odourless, highly flammable, diatomic gas, and is used especially in synthesis. Hydrogen can be produced a number of ways. They are i) electrolysis of water ii) reaction of a hydrocarbon with steams iii) from biomass

B. Biogas

Bio-gas is a stable and eco-friendly alternative resource of energy consideration by the high merit of its preparation from the immensely accessible natural and organic types of waste, the ease of manufacture, process as well as the continuance of the creation unit in line with the numerous features accrues at a nationwide and also the individual levels.

C. Engine setup

In this present investigation used the four-stroke single-cylinder water-based cooling diesel-engine with a capacity 3.5 kW with hydro dynamometer loading [12]. The diesel engine is converted into the dual-fuel mode by using the inlet manifold gaseous-fuel injection shown in the below Fig. 1. Hydrogen cylinder with a pressure of 135 bar was regulated by regulator and release at a pressure of 1 bar. The hydrogen has a high flammability nature so arranged a back flame arrestor for safety purpose [13]. The gas flow was maintained by sensors system controlled by a computer interface.

Fig. 1 Inlet Manifold Injection of gaseous fuel

D. Methodology

At the first stage of the investigation, the selected engine has been run by a single fuel mode with diesel. After that sends the diesel was pilot fuel and hydrogen gases secondary fuel with two mass flow rates 3 lpm and 4 lpm. In the second phase, the engine has been run with diesel as a pilot-fuel and biogas as subsidiary fuel with two mass flow rates 3 lpm and 4 lpm.

III. RESULTS AND DISCUSSION

The efficiency of the engine, emissions, and combustion features has been experimentally measured for two phases. All the parameters were discussed clearly in the below.

A. Performance characteristics

Fig. 2 depicts the deviation of brake-thermal efficiency feature with the loads as of single and dual-fuel mode of operations. The brake thermal efficiency of dual fuel mode with the flow rate of 4lpm of Hydrogen and Biogas shows significant enhancement when compared with the single fuel mode. The hydrogen and biogas with a flow rate of 3 lpm show approximately equal to the single fuel mode with diesel. The Fig. 3 depicts the deviation with specific-fuel consumption (SFC) and the load factor. Here, found that 4 lpm flow rate of hydrogen shows lower SFC due to a fast flame speed of hydrogen-fuel.

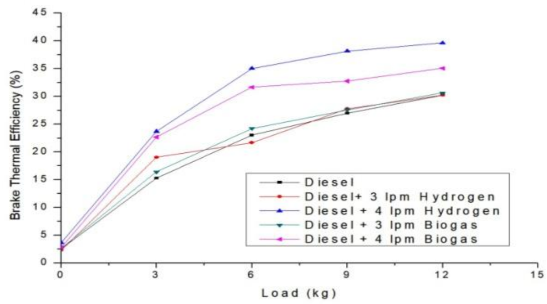

Fig. 2 Brake Thermal Efficiency V_S Load

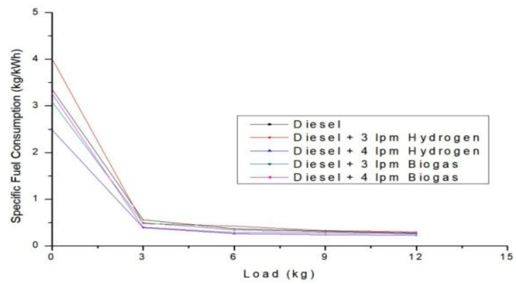

Fig. 3 Specific Fuel Consumption VS Load

B. Emissions characteristics

The experiments were carried out in a dual-fuel mode with the application of the various gases like hydrogen and biogas at two flow rates of 3 lpm and 4 lpm. The exhaust emissions were measured by using AIRREX automotive-gas analyzer and smoke have been measured by the use of AVL smoke-meter. In dual-fuel mode with bio-gas shows the significant decline of NO_X emission types for both the flow rates and increasing of hydrocarbons, CO, and other types of smoke emissions as of the comparative with the different operative circumstances. Fig. 4 depicts the deviation of NO_X emissions by means of all the operative conditions with loads.

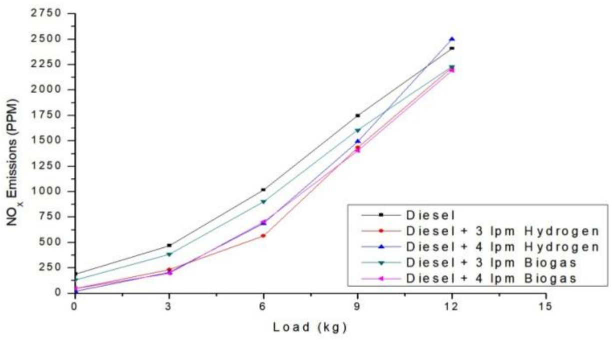

Fig. 4 NOX emissions VS Load

C. Combustion Characteristics

The engine setup was connected to the piezoelectric pressure transducers for measuring the cylinder pressure at all the crank angles [14]. The Fig.5 shows the relationship between the crank angles with cylinder pressure. From that, it was observed that the biogas operations showed higher combustion pressures when compared to the two hydrogen flow rates and pure diesel operation. The 4 lpm of biogas flow rate shows the maximum pressure of 65.78 bar at 365° of crank angle.

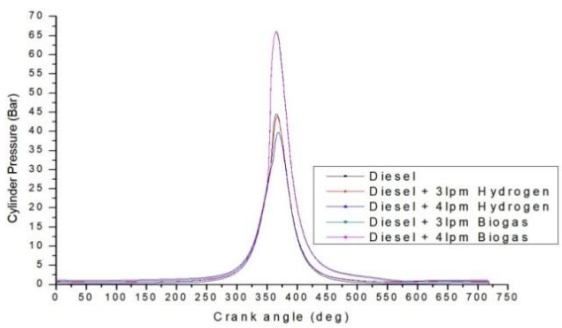

Fig. 5 Cylinder Pressure V_S Crank angle

IV. CONCLUSION

In the present investigation, diesel-engine was converted into dual-fuel mode without any major modification of current The present investigation the diesel engine. Here, Hydrogen and biogas as used as subsidiary fuel as well as diesel fuel as the pilot-fuel injection. The gases fuel was injected into the inlet manifold of the engine with two volume flow rates of 3 lpm and 4 lpm. The obtained result of the investigation has drawn the following conclusion points.

i) The brake thermal efficiency was shown enhancement at 4 lpm of both hydrogen and biogas operating condition.

ii) The 4 lpm of hydrogen flow shows the maximum brake thermal efficiency as 39.65%, and also it showed the lower specific fuel consumption compared with the other operating conditions.

iii) The hydrogen fuel used in dual fuel mode shows the higher rate of NO_X emissions when considered with the other operating conditions. This is due to the higher heat release rate of hydrogen.

iv) The biogas used in dual-fuel mode at a rate of flow with 4 lpm showed the 8.96% reduction NO_X emissions when compared with the single fuel mode with diesel.

V) The biogas in dual fuel mode at the rate of flow, 4 lpm reflects the brake-thermal efficiency as 35.05%. It is 15.90 % higher than the pure diesel operation.

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