International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 09 || September 2017 || PP. 53-58

An Experimental Investigation on Performance of Agricultural Stationary Diesel Engine Fueled With Hydroxy-Diesel Mixture as a Fuel

Anil Kumar Dhariwal[1], Nitin goyal[2], Ashish Nayyar[3]
[1,2,3] Mechanical Engineering Department, Swami Keshvanand Institute of Technology, Jaipur

Abstract: Due to predicted shortage of conventional fuels and their increasing application and use, there has been a growing interest in alternative fuels like bio fuels, methyl alcohol, ethyl alcohol, hydrogen, producer gas and acetylene, for internal combustion (IC) engine. Gaseous fuels are good for clean burning. A very effective technology in the present scenario for using Hydrogen in IC engine is HHO gas (Hydroxy Gas / Brown Gas / Oxyhydral Gas) generator, which produces a mixture of hydrogen and oxygen through electrolysis. In this study, Hydroxy Gas is produced by HHO kit (water electrolysis) and injected at the inlet manifold, as a supplementary fuel in a Single Cylinder, Four Stroke, Constant speed, Water Cooled, Direct Injection Diesel Engine. The collected data were analyzed for performance and exhaust emissions of engine. We got the favourable results of reduced brake specific fuel consumption (BSFC) and increased brake thermal efficiency (BTE).

Introduction

Energy is prime mover for economic growth and is essential part of a modern economy. Future economic growth depends merely on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly[1].

Rapid urbanization and rapid growth in the population has imposed increased pressure on the environment. Increasing population of vehicles and growth in the industrial and power sectors which emit tonnes of pollutants every day, further deteriorate air quality and exposed to more health risks.

Diesel fuel demand for India is almost six times more as compared to Gasoline, hence searching alternative to diesel is a natural choice [2].

Alternative fuel should be easily available, renewable, environmentally friendly, cost effective and techno-economically competitive and should fulfil environmental, energy and security needs without loss to engine performance

Health Effects of Diesel Engine

Diesel emission has adverse health effects such as cancer and other pulmonary and cardiovascular diseases. Particulate matter (PM) is main content of diesel engine exhaust. Particulate matter is a complex mixture of extremely small particles (soot) and liquid droplets, primarily incompletely burnt fuel. The small particles absorb other toxins from the engine and engine exhaust, which can cause adverse health effects. Fine particles below 10μm affect respiratory morbidity and mortality, causes chest disease. Exposure to diesel fumes leads to eye and nasal irritation. Chronic inhalation of diesel fumes leads to the development of a cough and sputum. Higher exposures may lead to acute symptoms, primarily affecting the conjunctive and upper respiratory tract. CO resulting from incomplete fuel combustion in enclosed spaces cause headaches, dizziness, and lethargy. The hydrocarbons (HC) contribute to smog and may cause lung irritation. NO_x is formed at high temperatures during diesel fuel combustion. NO_2 is the more reactive gas associated with significant health problems especially adverse respiratory effects.

Thermodynamic tests for engine performance evolution have found the feasibility of using a variety of alternative fuels such as hydrogen, electric battery technologies, compressed natural gas (CNG), liquefied petroleum gas (LPG), acetylene, ethanol, methanol, biodiesel, vegetable oil and other biomass sources in internal combustion engines.

Among the available alternative fuel options; hydrogen finds a prominent place to replace the present fossil fuels in IC engines. Hydrogen is available abundantly in nature and gives near zero-emissions when used in IC engines. Hydrogen is a long term, renewable, recyclable and non-polluting fuel. Hydrogen has some peculiar features compared to Hydrocarbon fuel, the most significant being the absence of Carbon. Very high burning velocity yield very rapid combustion and wide flammability. Limit of hydrogen varies from an equivalent ratio (ϕ) of 0.1-7.1, hence the engine can be operated with a wide range of Air/fuel ratio.

Hydrogen (H_2) has an outstanding potential for being a key factor in driving the Global Energy system [7]. H_2 is only one of many possible alternative fuels that can be derived from natural resources such as coal, oil shale and uranium from renewable resources. H_2 can be commercially produced from electrolysis of water and also by coal gasification. Several other methods such as thermochemical decomposition of water and solar photo electrolysis are available but presently used at the laboratory level rather than for commercial use.

The Properties of Hydrogen

The comparison of properties of Hydrogen, gasoline and diesel are as given in Table-1

Table-1: Properties of Hydrogen, gasoline and diesel fuel

Properties	Diesel	Unleaded Gasoline	Hydrogen
Chemical formula	H_2	C_8H_{18}	$C_{12}H_{23}$
Flame temperature (K)	2600	2473	2318
Auto ignition temperature (K)	453-593	500-753	858
Minimum Ignition Energy (mJ)	---	0.24	0.02
Stoichiometric Air Fuel Ratio on mass basis	14.5	14.6	34.3
Density at 16ºC and 1.01 Bar (kg/m^3)	833-881	721-785	0.084
Quenching distance at NTP (mm)	---	2	0.64
Diffusivity in Air (cm^2/s)	---	0.08	0.63
Net Heating Value (MJ/kg)	42.5	43.9	119.93
Flame velocity (m/s)	0.22–0.25	0.30-.50	2.65– 3.25
Octane number	30	87	130+
Molecular weight (g/mol)	2.015	110	0.2

Low ignition energy and a wide flammable range of Hydrogen enables engine to run at lean condition which are helpful for the enhanced engine economics and emission performance[9].

Hydrogen Production

Hydrogen is produced from a wide range of primary resources, employing a wide range of technologies. Despite its abundance occurrence in the universe, it does not occur freely on earth, as it reacts very rapidly with other elements Therefore, the majority of hydrogen is bound into molecular compounds. The hydrogen can be extracted from higher energy fossil fuels as well as lower energy water.

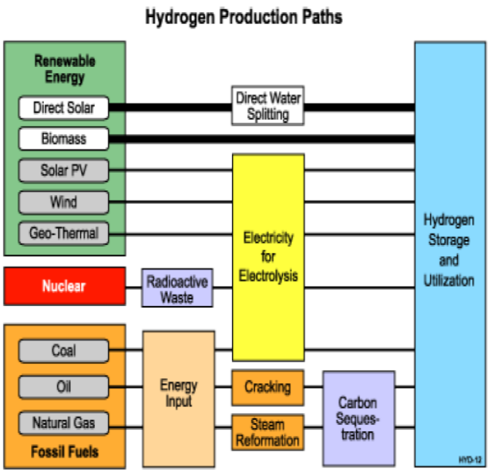

Figure 1Hydrogen Production Techniques

The hydrogen production from various techniques is summarized in Fig.1.

Experimental Set-up

Experimental test rig consists of a single cylinder, water cooled, four-stroke diesel engine (Kirloskar make, AV1 model) coupled with a hydraulic dynamometer. Test rig was Modified by Datacone Engineers Pvt. Ltd., Sangliwadi, India to measure various parameters required to determine the performance of the engine. A gas analyzer is used to measure the emission of the engine. The schematic diagram of test rig is shown in Fig.2.

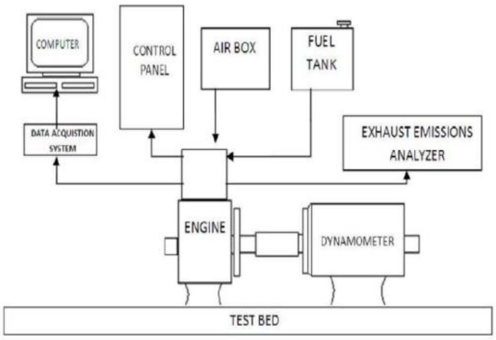

Figure 2 Engine Test Rig

The experimental setup mainly consists of following components:

Engine

Kirloskar make single cylinder diesel engine (model AV1) is used for current study. It is most versatile water cooled engine and is widely used for agriculture and electric generation purpose in India. ***Hydraulic dynamometer***

Hydraulic dynamometer is coupled with engine to measure torque. The power absorbing capacity of the unit increases as speed increases and is suitable for loading of I.C. engines, gas turbines and hydraulic turbines.

HHO generator kit

First the acrylic containers were manufactured using an 8mm thick acrylic sheet. Ana-Bond an industrial adhesive was used to firmly join all the sides of container, while, a semitransparent silicone gel was used for sealing the container. Special care had to be taken while using industrial adhesive.
The cell was made of SS plates of 316L grade. It is a very rare grade, only used for making tanks of highly corrosive chemicals. The plates were machined and cut in to size of 4” x 6”. This size was calculated to be most efficient considering all the points which shall enhance the electrolysis process. Tons of experiments were conducted for finding the best configuration for the maximum and most efficient HHO gas production. The present configuration i.e. [+ n n n - n n n +] with an average spacing of 0.8 mm (n = neutral), was found to be the best configuration.

Exhaust Gas Analyzer

Gas analyzer is used to measure concentrations of Carbon Monoxide (CO), Hydrocarbons(HC) and Carbon Dioxide (CO_2) based on Non-Dispersive Infra-Red principle and Oxygen (O_2) and Oxides of Nitrogen (NO_x) are measured by Electro Chemical principle.The analyzer is based on the principal that the quantity of infrared energy absorbed by a compound in a sample cell is proportional to the concentration of the compound in the cell. The analyzer is equipped with advanced microprocessor technology with printer and RS 232 serial port for a personal computer interface

AVL Smoke meter

Smoke meter is used to measure smoke density and smoke opacity based on the light absorption coefficient principle. The smoke meter is equipped with advanced microprocessor technology with printer and RS 232 serial port for a personal computer interface. The AVL Smoke Meter is a filter-type smoke meter for the measurement of the soot content in the exhaust of diesel engine. The variable sampling volume and the thermal exhaust conditioning ensure an extremely high reproducibility and a wide range of application. The instrument can be used not only on large engines but also on light duty engines independent of their generation.

Performance Characteristics of Engine

Brake specific fuel consumption (BSFC)

Brake specific fuel consumption is themeasure of fuel consumption per kW of brake power. It is observed from Fig.3 that BSFC decreases with increase in the load, and it again tends to increase just near to full load. BSFC is calculated in kg/kW-h for all set of tests.

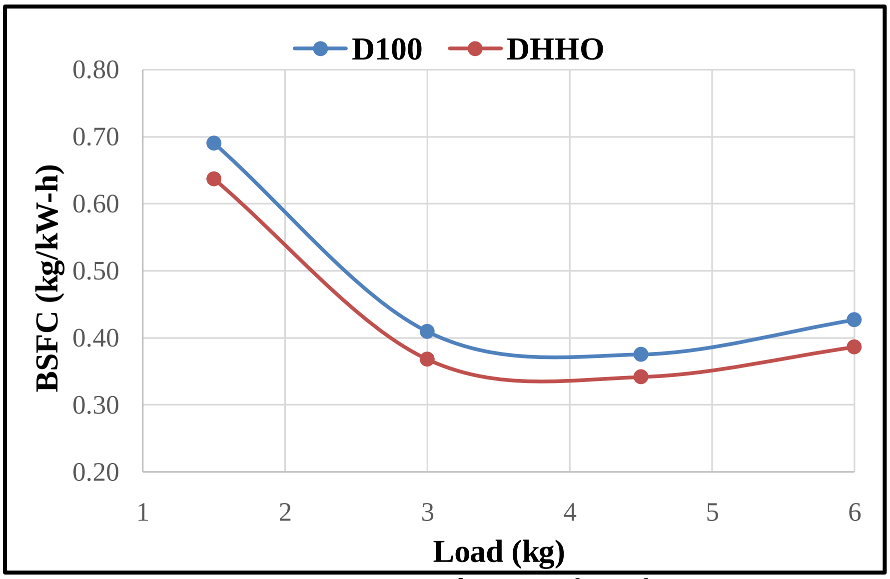

Figure 3 Variation Of BSFC with Load

It was observed that at whole range of loads the BSFE was lower for diesel-Hydroxy mixture (DHHO) than that of diesel only (D100). At full load condition the BSFC is 9% less for DHHO than that of D100. The reduction in BSFC is because of increased calorific value of combustible mixture due to addition of OH with inlet air. Due to better combustible properties of Hydroxy gas, DHHO mixture lead towards the complete combustion which in result reduces CO content in cylinder. Thus more power is obtained with less amount of fuel.

Brake thermal efficiency (BTE)

Brake thermal efficiency (BTE) is the ratio of the power output to the energy input through fuel injection. The energy introduced by the fuel injection is product of mass of fuel and calorific value of fuel. BTE increases with respect to the load and maximum at nearly 90% of full engine load. Variation of BTE with load is shown in Fig.4.

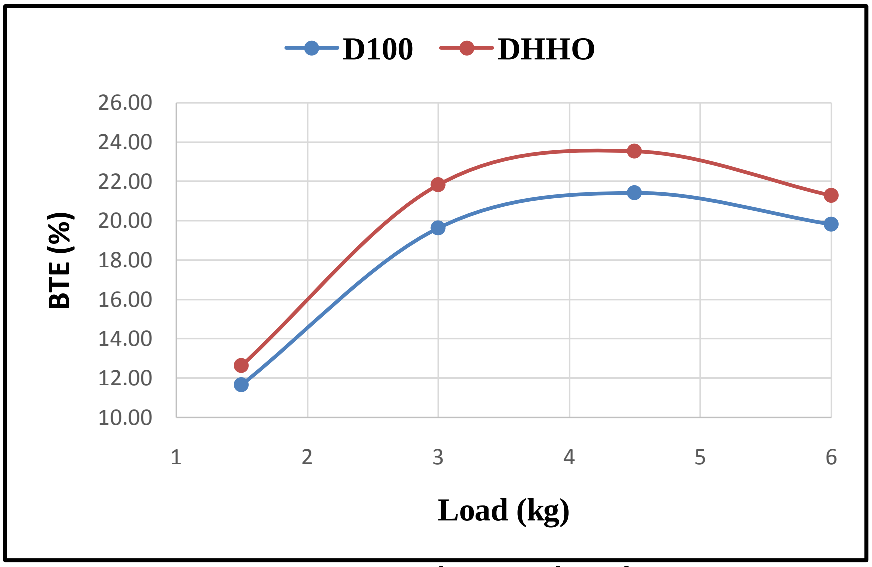

Figure 4 Variation Of BSFC with Load

As shown in Fig.4, BTE increases with increase in load (this is usual trend of diesel engine) and at full load it is going to decline. At full load condition the BTE is improved by 7% for DHHO than that of D100. At higher loads the fraction of HHO (calorific value 119000 kJ/kg) increased in fuel mixture this also increased heating value of fuel mixture and result in higher thermal efficiency.

Conclusions

The following conclusions are drawn from experimental work:

The HHO generation kit has been fabricated and installed with single cylinder diesel engine test rig. Experiments have been performed with diesel only and mixture of diesel and Hydroxy gas.

It has been observed that with 1.5 liter/min mixing of hydroxy gas with diesel improve the performance of engine. The BSFC has been reduced by 9% and BTE has been improved by 7%.

References

[1]. S. Gyanendra, "An analytical approach to farm mechanization in India-Agricultural machinery development and promotion," *Journal of Rural Development,* vol. 7, no. 2, pp. 297-319, 1999.

[2]. M. S. B. K. Baranwal, "Prospects of biodiesel production from vegetable Oils in India," *Renewable and sustainable Energy Review* , vol. 9, pp. 363-378, 2005.

[3]. KPMG, "Agriculture Equipment Sector in India: A Report," India Brand Equity Foundation, India, New Delhi, 2009.

[4]. D. O.A.A.C. Directorate of Economics and statistics, "Agricultural statistics at a glance," Ministry of Agriculture, Government of India, New Delhi, 2017.

[5]. K. Research, "Indian agriculture equipment market outlook to 2017," Ken Research, New Delhi, 2013.

[6]. P. H. G. Praveen A. Harari, "Thumba biodiesel as an alternative fuel for CI engine: Review," *International Journal of advance research and innovative ideas in education,* vol. 1, no. 3, pp. 476-480, 2015.

[7]. M. K. R. L.Barreto, "The Hydrogen in the 21st Century, a sustainable development scinario," *Internantional Journal of Hydrogen Energy,* vol. 28, pp. 267-284, 2003.

[8]. N. G. D. C. K. K. Saravanan N., "Exprimental investigation of hydrogen port fuel injection in DI engine," *Ineternational Journal o Hyrogen Energy,* vol. 32, pp. 4071-4080, 2007.

[9]. Y. W. Fanhua Ma, "Study on the extension of lean operation limit through hydrogen enrichment in a natural gas spark-ignition engine," *Internation Journal of Hydrogen Energy,* vol. 33, p. 1416– 1424, 2008.

[10]. S. K. V. K. G. N. Parashuram R Chitragar, "Use of hydrogen in internal combustion engines: A comprehensive study," *Journal of Mechanical Engineering and Biomechanics,* vol. 1, no. 3, pp. 84-96, 2016.

[11]. "http://www.fsec.ucf.edu/en/consumer/hydrogen/basics/images/HydrogenProductionPaths.gif.," [Online]. Available: http://www.fsec.ucf.edu. [Accessed 9 September 2017].

[12]. D. A. V. K. Rasik S. Kaware, "Effect of hydroxy (HHO) gas addition on performance and exhaust emission in spark ignition (SI) engine," *International Journal of Innovative Research in Science, Engineering and Technology,* vol. 5, no. 10, pp. 17913-17920, 2016.

[13]. V. K. Rasik S Kuware, "Effect of hydroxy gas addition on performence and emission of spark ignition engine," *Internation Journal of Trend in Reasearch and Development,* vol. 3, no. 6, pp. 511-15, 2016.

[14]. G. N. K. K. C. D. N Saravanan, "An Experimental investigation on hydrogen as a dual fuel for diesel engine system with exhaust gas recirculation technique," *Renewable Energy,* vol. 33, pp. 422-427, 2008.

[15]. G. N. G. S. C. D. K. K. N. Saravanan, "Combustion analysis on a DI diesel engine with hydrogen in dual fuel mode," *Fuel,* vol. 87, p. 3591–3599, 2008.

[16]. M. F. Christodoulou, "Experimental investigation of the effects of separate hydrogen and nitrogen addition on the emissions and combustion of a diesel engine," *International Journal of Hydrogen Energy,* vol. 38, p. 10126–10140, 2013.

[17]. E. U. K. A. Ali Can Yilmaz, "Effect of hydroxy (HHO) gas addition on perfonnance andexhaust emissions in compression ignition engines," *Internation Journal of Hydrogen Energy,* vol. I, no. 35, pp. 1366-1372, 2010.

[18]. A. A.-R. Sa'ed A. Musmar, "Effect of HHO gas on combustion emissions in gasoline engines," *Fuel,* vol. 90, pp. 3066-3070, 2011.

[19]. Y. W. H. L. Y. L. J. W. S. Z. Fanhua Ma, "Experimental study on thermal efficiency and emission characteristics," *International Journal of Hydrogen Energy,* vol. 32, pp. 5067-5075, 2007.

[20]. K. G.-R. Stanislaw Szwaja, "Hydrogen combustion in a compression ignition diesel engine," *Internation Journal of Hydrogen Energy,* vol. 34, pp. 4413-442I, 2009.

[21]. R. B. N. M. Senthil Kumar, "Use of hydrogen to enhance the performance of a vegetable oil fuelled compression ignition engine," *International Journal of Hydrogen Energy,* vol. 28, pp. 1143-1154, 2003.

[22]. T. M. S. A. N. T. Y. Tsujimura, "A study of direct injection diesel engine fueled with hydrogen," *SAE Technical Paper 2003-01-0761*, 2003.

[23]. Y. A. E. M. E. K. Mohamed M. EL-Kassaby, "Effect of hydroxy (HHO) gas addition on gasoline," *Alexandria Engineering Journal*, vol. 55, pp. 243-257, 2016.

[24]. M. R. A. Masood M, "Computational combustion and emission analysis of hydrogen-diesel blends with experimental verification," *International Journal of Hydrogen Energy,* vol. 32, p. 2539–2547, 2007.

[25]. N. N. A. C. e. a. Constantin Panaa, "Experimental aspects of the hydrogen use at diesel engine," *Procedia Engineering,* vol. 181, pp. 649 - 657, 2017.

[26]. P. E. S. M. Prithirajan K., "The performance of IC engine with diesel-hydrogen dual fuel," *International Journal of Advances in Mechanical and Civil Engineering,* vol. 2, no. 3, pp. 73-79, 2015.

[27]. S. M. N. R. R. S. M. P. B. B. Rahul R. Shitole, "Performence of hydroxy has in diesel engine," *Internation Journal of Advance Research, Ideas and Innovation in Technology,* vol. 3, no. 2, pp. 413-35, 2017.