iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** X **Month of publication:** October 2019

DOI: http://doi.org/10.22214/ijraset.2019.10049

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue X, Oct 2019- Available at www.ijraset.com

Experimental Investigations on the Performance and Emissions of Dual Fuel along with Engine modification in a DI Compression Ignition Engine

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Abstract: ***The use of alternative fuels for CI engine has received renewed attention during the last decade. These engines consumes heavy quantity of fuel, where these engines produce bulk power as well as there also produces the different types of toxic emissions that harmful to the living beings and environment. The best method of tackling these problems are by using hydrogen fuel inducted in the intake manifold along with air and some design modification of the engine piston. In this experimental investigation hydrogen was inducted into the intake manifold along with air, while diesel was injected directly inside the cylinder. The in-cylinder air motion in internal combustion engines is one of the most important factors controlling the combustion process. It governs the fuel-air mixing and burning rates in diesel engines. This can be achieved by drilling holes in the piston crown. In this study, a Direct Injection (DI) diesel engine was tested with dual-fuel (hydrogen-diesel) mode operation with piston modification. The performance and emission characteristics was evaluated and compared with neat diesel operations.***

Keywords: Dual fuel , piston bowl geometry ,performance, emissions, drilled hole, pressure, Compression ignition engine.

I. INTRODUCTION

Many researchers have been directed towards the development of alternative fuels to achieve the goal. Among the various alternative fuels hydrogen is found to be most promising due to its clean burning and better combustion properties. Hydrogen has superior characteristics then hydro carbon fuels such as flammability limits ignition energy and high flame speed. The aim of this project work is to investigate the effect of hydrogen addition on performance and emission when hydrogen is added to a diesel-fuelled CI engine at different loads with little modification to the piston.

A. Toxicity

Hydrogen is non-toxic but can act as a simple asphyxiant (causes suffocation) by displacing the oxygen in the air.

B. Leakage

The molecules of hydrogen gas are smaller than all other gases, and it can diffuse through many materials considered airtight or impermeable to other gases. This property makes hydrogen more difficult to contain than other gases. Leaks of liquid hydrogen evaporate very quickly since the boiling point of liquid hydrogen is so extremely low.

C. Flashpoint

All fuels burn only in a gaseous or vapor state. Fuels like hydrogen and methane are already gases at atmospheric conditions, whereas other fuels like gasoline or diesel that are liquids must convert to a vapour before they will burn. The characteristic that describes how easily these fuels can be converted to a vapour is the flashpoint. The flashpoint is defined as the temperature at which the fuel produces enough vapours to form an ignitable mixture with air at its surface.

D. Flammability Range

The flammability range of a gas is defined in terms of its lower flammability limit (LFL) and its upper flammability limit (UFL). The LFL of a gas is the lowest gas concentration that will support a self-propagating flame when mixed with air and ignited. Below the LFL, there is not enough fuel present to support combustion; the fuel/air mixture is too lean. The UFL of a gas is the highest gas concentration that will support a self-propagating flame when mixed with air and ignited. Above the UFL, there is not enough oxygen present to support combustion; the fuel/air mixture is too rich. Between the two limits is the flammable range in which the gas and air are in the right proportions to burn when ignited

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E. Electro-Conductivity

Hydrogen has the added property of low electro-conductivity so that the flow or agitation of hydrogen gas or liquid may generate electrostatic charges that result in sparks. For this reason, all hydrogen conveying equipment must be thoroughly grounded.

F. Ignition Temperature

hydrogen, the auto-ignition temperature is relatively high at 1085ºF (585ºC). This makes it difficult to ignite a hydrogen/air mixture on the basis of heat alone without some additional ignition source. this is reason why hydrogen cannot be used as a sole fuel in diesel engines.

G. Energy Content

The calorific value of hydrogen is 120 MJ/Kg, which is almost three that of diesel. This high energy content is one of the reasons why hydrogen is tried for usage in IC engines.

Table. 1 hydrogen properties

Hydrogen fuel properties	Values at 25°C and 1 atm
Density (kg/m^3)	0.08988
Auto ignition temperature in air (K)	858
Flame velocity (m/s)	1.85
Adiabatic flame temperature (K)	2480
Lower heating value (MJ/kg)	119.7
Heat of combustion (MJ/kg)	3.37

Table .2 Engine specifications

Make	Kirloskar AV-1
Type	Single cylinder, water cooled, 4- stroke diesel engine
Bore	87.5 mm
Stroke	110 mm
Cylinder arrangement	Vertical
Maximum power	3.7 kW (5HP)
Speed	1500 rpm
Loading device	Eddy current Dynamometer

II. ENGINE MODIFICATION

The modifications of engine design, particularly combustion chamber may be required, because mixture formation within the engine cylinder mainly depends upon the shaper of the combustion chamber in a Compression ignition engine.

A. Modified Piston Bowl Geometry

In the present investigation, radially drilled holes were provided on the top side of the piston. Six no. of holes were drilled on the piston with equal angle by varying diameters (Ø 2.5mm axial Ø 2.5mm inclined and Ø 3.5mm axial)

B. Hydrogen Admission

The engine was modified to operate on hydrogen. Hydrogen Is admitted into the inlet manifold which is 50 cm from the inlet valve of the engine. A high pressure hydrogen cylinder is used having inlet pressure of approximately 280 bar.

C. Hydrogen Supply

The hydrogen gas is allowed to pass through the intake pipe at an outlet pressure of 2 bar pressure and at flow rate of 8LPM, 10LPM, 12LPM, 16LPM, and 20LPM.the pressure is regulated by a double stage diffusion pressure regulator mounted on the hydrogen cylinder

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III. EXPERIMENTAL SETUP AND PROCEDURE

Hydrogen is supplied from a high pressure of 120 bar reduced to 2 bar using hydrogen pressure regulator. An imported high quality double stage diffusion pressure regulator was employed to reduce the hydrogen pressure from 120 bar to 2 bar. Hydrogen is then passed through a flame arrestor, used to suppress the explosion inside the hydrogen containing system. The flame arrestors operate on the basic principle that the flame gets quenched if sufficient heat can be removed from the gas by the arrestor. Hydrogen is than passed through a fine control valve to adjust the flow rate of hydrogen. Then it passed through the flow meter, which meters the flow of hydrogen in terms of Lpm. Finally hydrogen was admitted into the intake manifold at a distance of 50 cm from the inlet valve, where it mixed with air and this hydrogen-air mixture was inducted into the engine cylinder. The photographic view of the experimental setup is shown in figure. At first the engine was operated with neat diesel and the performance, emission parameters were evaluated. The compressed hydrogen gas was introduced by induction technique through the intake manifold at 2bar pressure at the flow rate of 8LPM, 10LPM, 12LPM, 16LPM and 20LPM. The performance and emission parameters were measured and compared with that of diesel baseline test readings.



Figure: 1 Photographic view of experimental setup

IV. RESULT AND DISCUSSIONS

In this chapter, experimental results are obtained under different flow rate of hydrogen namely 8LPM, 10LPM, 12LPM, 16LPM, 18 LPM, 20 LPM and different piston design configurations with neat diesel operation of the engine have been presented and discussed. The engine speed was maintained at 1500 rpm in all modes of operation. The engine load is varied from 0% to 100% in step of 20%. The performance and emission characteristics of the engine were analyzed and as follows**.**

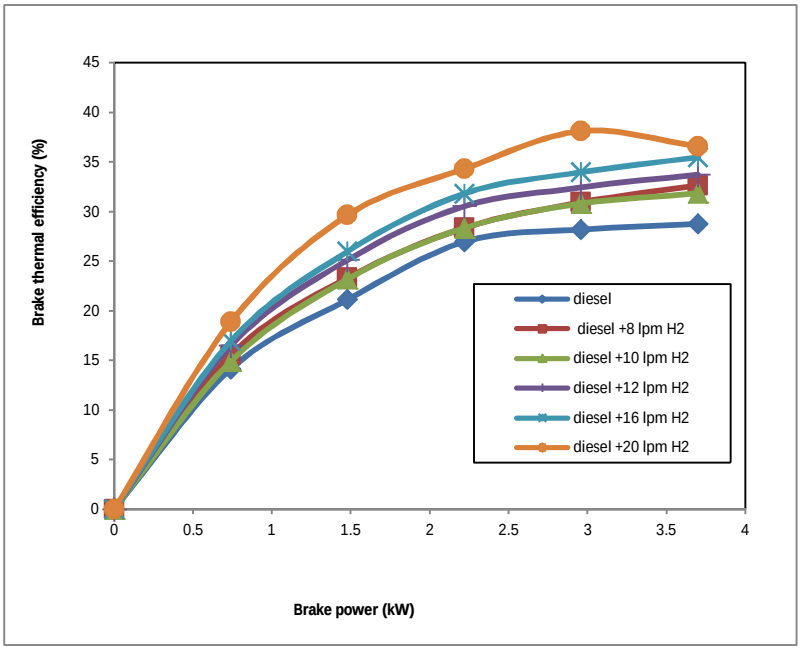


Figure: 2 Variation of brake thermal efficiency with brake power Ø 2.5mm axial hole modified piston

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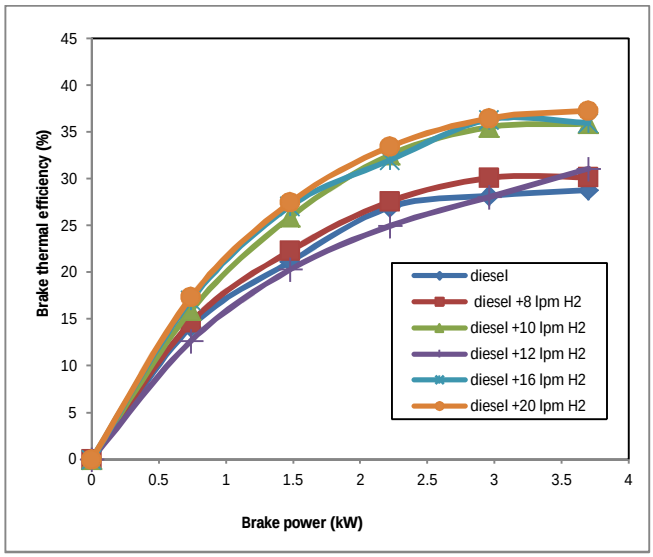


Figure: 3 Variation of brake thermal efficiency with brake power of Ø 2.5mm inclined hole modified piston

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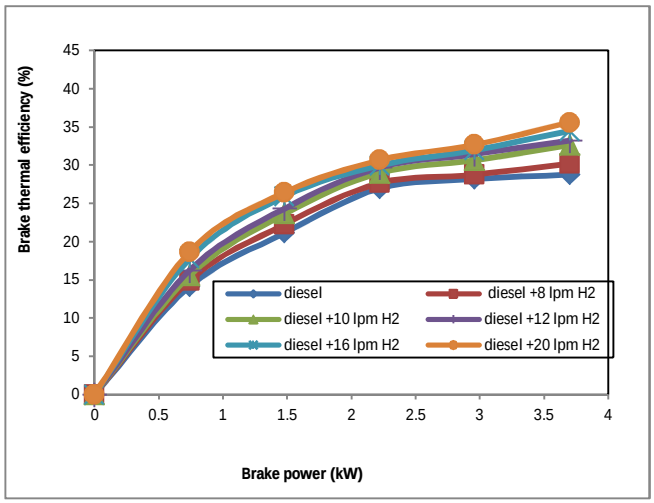


Figure: 4 Variation of brake thermal efficiency with brake power of Ø 3.5mm Axial hole modified piston

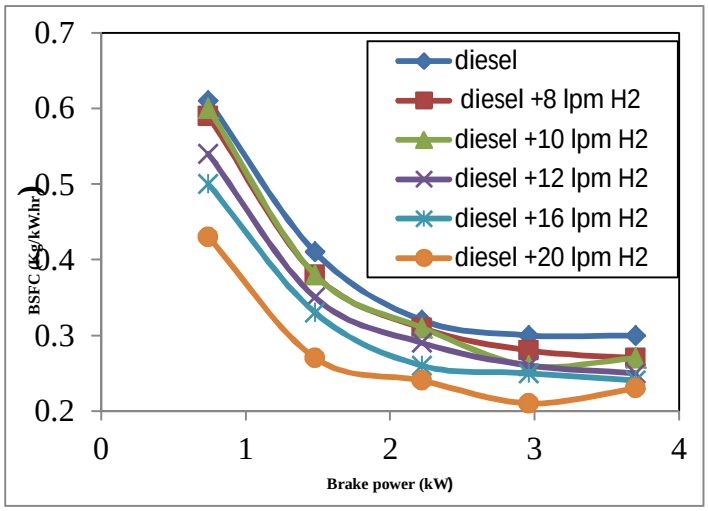


Figure: 5 Variations of brake specific fuel consumption with brake power of Ø 2.5mm axial hole modified piston

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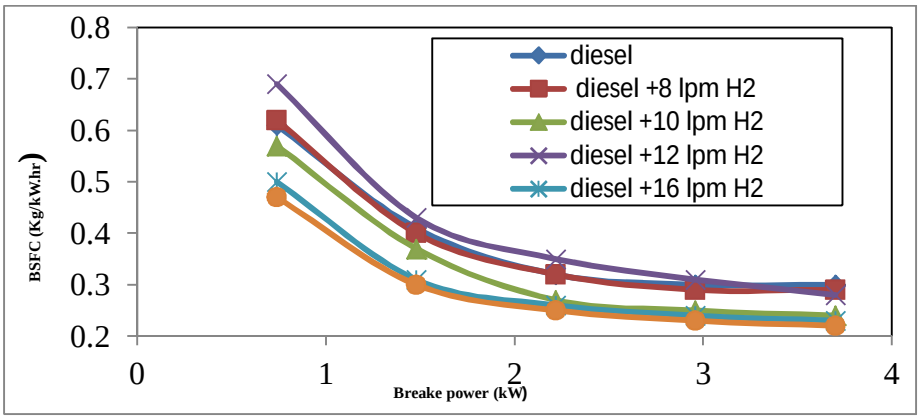


Figure:6 Variations of brake specific fuel consumption with brake power of Ø 2.5mm inclined hole

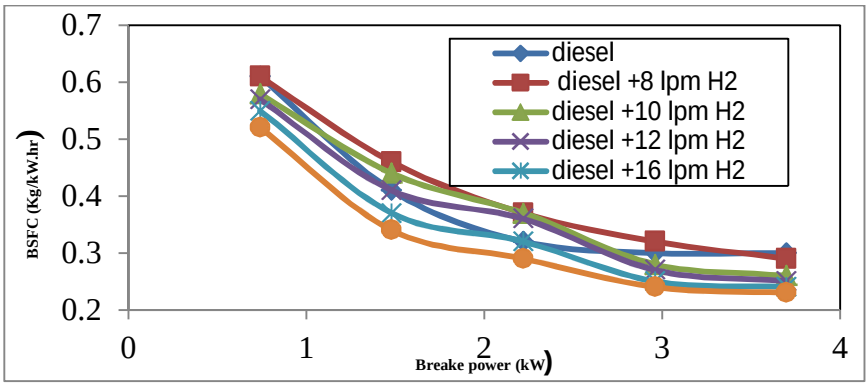


Figure:7 Variations of brake specific fuel consumption with brake power of Ø 3.5mm axial hole modified piston

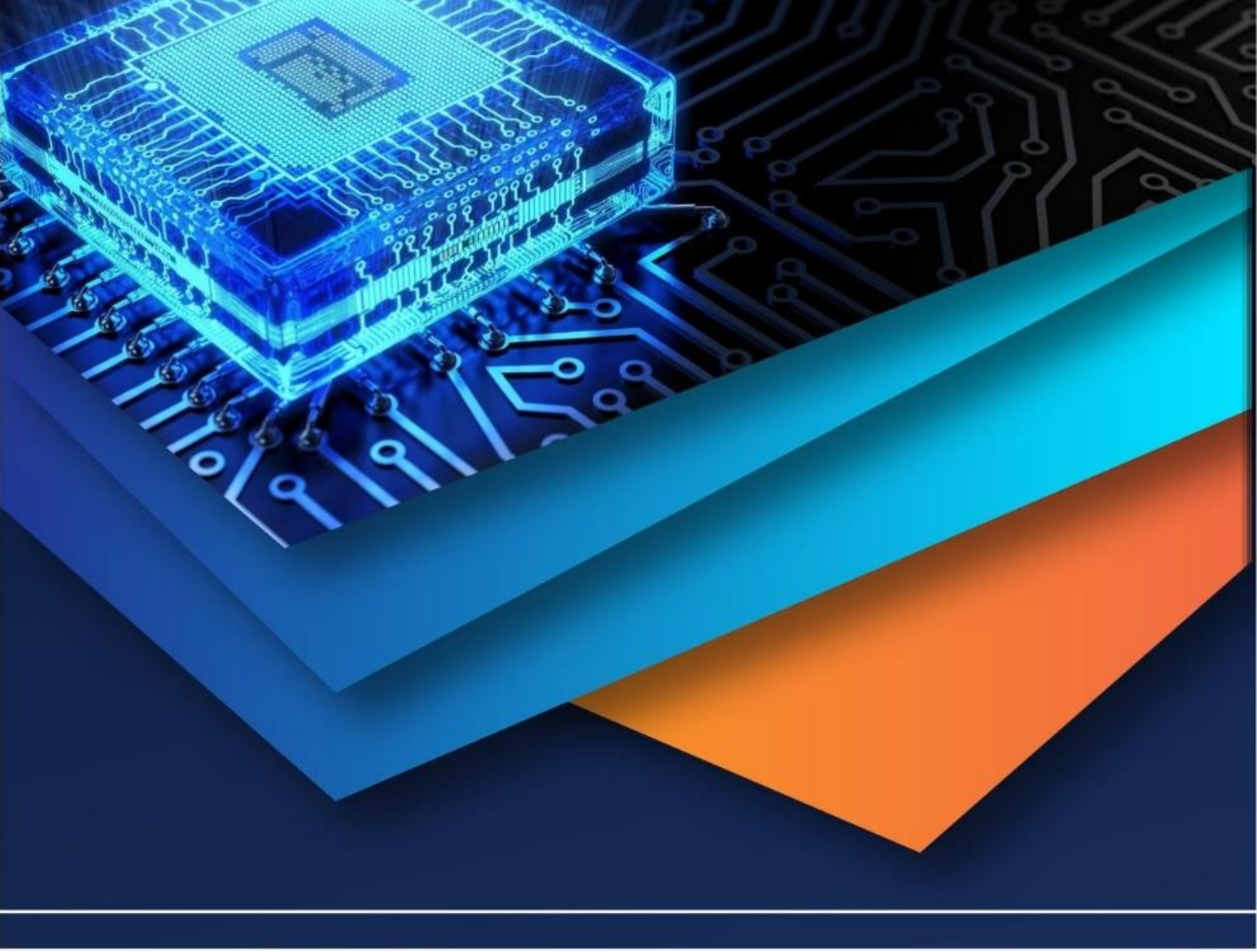
V. CONCLUSION

Based on the experimental results for the single cylinder direct injection diesel engine with different piston configurations and various hydrogen enrichments such as 8 LPM, 10 LPM, 12 LPM, 16 LPM, and 20 LPM , the following conclusions are drawn. The BSFC of diesel engine with Ø 2.5 mm inclined hole piston design configuration with 20 LPM hydrogen enrichment is decrease by about 32.4 % compared to neat diesel at peak load operation. For Ø 2.5 mm axial hole piston and 3mm axial hole piston the BSFC is about 25.6% and 22.2% lower than neat diesel at same load conditions. The brake thermal efficiency of diesel engine with Ø 2.5 mm inclined hole piston design configurations with 20 LPM hydrogen enrichment is increased by about 8.24 % compared to neat diesel at full load operation. For Ø 2.5 mm axial hole piston the brake thermal efficiency is about 7.53 % higher than neat diesel and Ø 3.5mm axial hole piston the brake thermal efficiency is about 6.36% higher than neat diesel at same load conditions. The exhaust gas temperature increased for Ø 2.5 mm inclined hole piston with 20 LPM hydrogen addition, compared to neat diesel operation. The HC and CO emission was decreased for Ø 2.5 mm inclined hole piston with 20LPM hydrogen addition compared to neat diesel operation. Finally, it is concluded that out of three different piston design configurations, Ø 2.5 mm inclined drilled hole on the piston crown with 20 LPM hydrogen induction proved to be better in all aspects.

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