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Dual fuel mode DI diesel engine combustion with hydrogen gas and DEE as ignition source

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Highlights

- Complete elimination of carbon based fuels like petrol and diesel.
- Gaseous Hydrogen inducted in the intake port to eliminate the emission.
- DEE inducted through manifold to avoid the diesel fuel.
- H_2+DEE+Diesel performance and emission characteristics are plotted.
- Performance and emission characteristics compared with basic diesel operation.

Abstract

During the past two decades considerable effort has been taken to develop and introduce alternate source of energy for the conventional gasoline and diesel. Environmental pollution and uncertainty in cost of petroleum products are the principal driving forces for this movement. The major pollutants from a diesel engine system are NO_x, Smoke, particulate matter and Soot. Several alternative fuels were tried but all of them are carbon based fuels, therefore net carbon based pollutants cannot be reduced. One alternative to carbon based fuels is hydrogen, a non-carbon fuel, can only meet zero emission vehicles standards in future. Hydrogen can be commercially used as a fuel even though it has a number of technical and economical barriers. In the present investigation hydrogen is used in a diesel engine in the dual fuel mode and in neat form using DEE. In neat form DEE is injected into the intake manifold. In order to have a precise control of hydrogen flow and to avoid the backfire and pre-ignition problems, hydrogen is injected into the intake port and DEE injection follows hydrogen injection. DEE mixes with air and flows into the combustion chamber and DEE auto ignites first followed by hydrogen combustion. A single cylinder-four stroke water-cooled naturally aspirated constant speed D.I. diesel engine with a rated output of 3.7 kW at 1500 rpm is used for the experimental work. Measurements are taken with respect to the performance, combustion and emission studies. Experiments are conducted to determine the optimized injection timing, injection duration and injection quantity of the fuel in port injected operated engine using diesel as an ignition source for hydrogen. Experiments are conducted using hydrogen-DEE and with DEE injection quantity is optimized.

Introduction

Diesel engine is one of the most efficient types of heat engines and is widely used as a prime mover for many applications such as Automobiles, Tractors, Earth movers, Prime movers, Agriculture etc., The main reason for using diesel engine is its higher thermal efficiency, durability, better torque characteristics and low cost of the diesel fuel (Heywood 1989). Techniques like water injection, exhaust gas recirculation (EGR), diesel oxidation catalyst (DOC), selective catalytic reduction (SCR), Diesel particulate filter are adopted in the present day diesel engines in order to meet the ever increasing stringent emission norms. Another technique for meeting the emission norms may be partial replacement of gaseous fuels like hydrogen. Gaseous fuels have the advantage with respect to combustion, emissions and efficiency of the engine. Especially hydrogen has a major advantage since it is a carbon free fuel, which makes the combustion to be free from CO, CO_2, HC, smoke and soot emissions. However, major pollutant in a hydrogen-operated engine is NOx emission. The hydrogen operated dual fuel engine has the property to operate with lean mixtures at part load and no load, which results in NOx reduction, and increase in thermal efficiency of the engine thereby reducing the fuel consumption. It is also found that hydrogen could be substituted for diesel up to 38% on volume basis without loss in thermal efficiency, however with a nominal power loss. In recent days, the significance of environment and energy is more accentuated because, among various energy sources, the fuels for automotive use are drawing attention as they are directly associated with our day to day life. The fossil fuels, which are widely used nowadays, have some grave problems such as restriction over preservation, unfeasible for recycling and it also produces various kinds of toxic waste emanation [12]. Therefore, various researches were carried on alternative fuels to substitute the fossil fuels. Among them, hydrogen has the outstanding advantages of wide flammable assortment and will also not produce unburned hydrocarbon and carbon monoxide [1], [2], [3], [4], if there are no lubricants in the combustion chamber. In order to adopt, gaseous hydrogen as a fuel for an international engine, lots of research were carried out on hydrogen supply system [2], [10], [13], combustion characteristics [5], [6] and so on. And many areas of research are concerned with the adoption of in-cylinder type injection system for high pressure hydrogen. This type of injection system can eliminate the possibility of backflow of hydrogen into the intake pipe and can as well produce more power than an intake port injection system. But this system has a very complicated structure and greater durability problem. To overcome the disadvantages of high pressure in cylinder, injection system was tried with timed injection [11]. In this study, an intake port injection system was constructed and installed on a single cylinder engine, using a solenoid as the driving source of the injection valve. In order to minimize the possibility of flashback occurrence, injection timing of the hydrogen injection valve was set within the duration of intake valve opening [7]. Specifically, the hydrogen is supplied while the intake valve is open. So that the hydrogen injected into the intake port could be inducted into the combustion chamber as much as possible [8], [9]. With this system, performance and emission characteristics of hydrogen combustion in the internal combustion engine were investigated.

Section snippets

Experimental setup

The engine used for the experimental investigation was a Kirloskar AV1, single cylinder, four strokes, cooled water, direct injection diesel engine, developing a rated power of 3.7 kW at a rated speed of 1500 rpm. The specifications of the test engine are given in

Table 1. The engine is coupled to water cooled eddy current dynamometer for loading. The engine is mounted on an engine test bed with suitable connections for lubrication and for the supply of cool water. The electronic control unit …

Experimental procedure

Hydrogen gas is stored on a high-pressure cylinder, which is at 150 bars, is reduced to a value of 1–2 bar by using a pressure regulator. Hydrogen is then passed through a fine control valve to adjust the flow rate of hydrogen. Then hydrogen is allowed to pass through dry type flame back arrestor and mass flow controller, which meters the flow of hydrogen in terms of Standard Liters per Minute (SLPM). Hydrogen is then passed through again dry flame arrestor, and wet flame arrestor, which is …

Instrumentation

The following instruments are utilized for measuring various parameters. Table 4 shows the complete instrumentation list. …

Brake thermal efficiency

The variation of brake thermal efficiency with load is depicted in Fig.3. It is observed that with DEE operation the brake thermal efficiency of the engine increases. At 25% load the brake thermal efficiency of hydrogen-DEE operated engine is 22% compared to diesel of 11% and 23% for hydrogen diesel operated engine. At 100% load the brake thermal efficiency is observed to be 34% for hydrogen-DEE and 32% for hydrogen diesel dual fuel engine whereas for diesel it is observed to be 25%. The …

Conclusion

Hydrogen gas port injection starting timing at TDC with duration of upto 63° [7 ms] is optimum for hydrogen-diesel operated engine. In the same conditions the DEE manifold injection starting at 18° ATDC with duration upto 27° [3 ms] optimum for Hydrogen-DEE-Diesel operated engine was observed. Table 5 shows the effect of performance and emission results of various injection timings with durations of hydrogen and DEE are recorded. Based on the performance and emission control the 7 slpm of …

Acknowledgment

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Exploration of the dual fuel combustion mode on a direct injection diesel engine powered with hydrogen as gaseous fuel in port injection and diesel-diethyl ether blend as liquid fuel

2024, International Journal of Hydrogen Energy

> *Citation Excerpt :*
> …It may be attributed to the increased cetane index in the blends, by the addition of DEE [35–37]. Another possible cause of lower cylinder pressure in case of the DDEE blends with H2 injection is owing to the higher latent heat of vaporization of DEE, that may absorb the local heat during its spray with diesel [38]. Similar pattern of the cylinder pressure was also observed by Saravanan et al. [22].…

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Use of hydrogen in dual-fuel diesel engines

2023, Progress in Energy and Combustion Science

> *Citation Excerpt :*
> …The high volatility, structural oxygen content, and high cetane number of some oxygenated additives could cause localized stoichiometric air/fuel ratio conditions, improving the combustion quality and increasing the cylinder pressure [179]. However, oxygenated additives might lower the cylinder pressure of hydrogen-fueled diesel engines because of possessing a higher latent heat of vaporization [181,182]. Therefore, adding oxygenated additives could reduce the inlet and overall charge temperature, reducing combustion chamber pressure [181,182].…

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The Influence of Hydrogen Induction on The Characteristics of a CI Engine Fueled with Blend of Camphor Oil and Diesel with Diethyl Ether Additive

2023, International Journal of Hydrogen Energy

> *Citation Excerpt :*
> …Further addition of the 10% DEE with 8 LPM owes to better combustion due to cetane enhanced ability; in the meantime, the addition of 20% DEE declined the heat release rate due to the prolonged dynamic injections [92]. The higher heat release rate with the addition of hydrogen gas is due to its high flame speed and reactivity [50]. Thiyagarajan.…

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Modeling study of hydrogen or syngas addition on combustion and emission characteristics of HCCI engine operating on iso-octane

2018, Fuel

> *Citation Excerpt :*

> …The addition of hydrogen to hydrocarbons can improve engine thermal efficiency due to essentially higher (almost in three times) energy density of hydrogen as compared with the commonly used fuels for IC engines [8,9,12]. Moreover, the emission of CO, CO2, CxHy, and soot decreases during burning of hydrogen-enriched fuels due to the smaller carbon content [1,2,4–12]. The emission of NOx depends on the engine operating regime and can be less [7,8,11,12] or higher than that with the pure hydrocarbon fuel operation [1,6,8–10].…

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Performance and emission characteristics of CIE using hydrogen, biodiesel, and massive EGR

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Experimental exploration of hydrogen enrichment in a dual fuel CI engine with exhaust gas recirculation

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