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

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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

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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 [1–4], 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 [2,13,10], 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.

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 (ECU) controls the operation of H_2 and DEE fuel injector. The one end of the positive power supply from the 12 V battery is connected to the injector; the other negative terminal of the injector is connected to the ECU, which is having the control of injector opening timing and duration. The electronic control unit is also having the input from the infrared detector. The IR Detector is used to give the signal to the ECU for the injector opening timing. The negative terminal of the injector is connected to the ECU. Based on the preset timing, the duration the injector will be opened for injection and closed after injection. The injection timing and injection duration will vary within the specified range by using the knob control. The power supply for the injector opening is 4A and for holding the injector to inject the fuel 1A will be the power supply required. Based on the presetting, the hydrogen will flow and the flow of hydrogen can be controlled either by using the pressure regulator or by using the digital mass flow controller. DEE injector is fixed in the intake manifold for DEE injection and the electronic fuel pump was fixed for the purpose of DEE supply. 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; DEE injection follows hydrogen injection. DEE mixes with air and flows into the combustion chamber and DEE auto ignites first followed by hydrogen combustion. Rota-meter is used to maintain the water flow, at the outlet of the engine. The range of the rota meter varies from 0 to 1000 lpm. Fig. 1 shows the experimental setup. Fig. 2 shows the photographic view of the experimental setup.

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

Table 1 – Specifications of test engine.

Make & Model	Bore (mm)	Stroke (mm)	Swept volume (CC)	Clearance volume (CC)	Compression ratio	Rated output	Rated speed (rpm)	Combustion chamber & cooling
Kirloskar, AV1, CI, 4-Stroke, single cylinder	80	110	553	36.87	16.5: 1	3.7 kW @ 1500 rpm	1500	Hemispherical open, water cooled engine