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Effect of hydrogen on ethanol–biodiesel blend on performance and emission characteristics of a direct injection diesel engine

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ABSTRACT

Environment issue is a principle driving force which has led to a considerable effort to develop and introduce alternative fuels for transportation. India has large potential for production of biofuels like biodiesel from vegetable seeds. Use of biodiesel namely, tamanu methyl ester (TME) in unmodified diesel engines leads to low thermal Efficiency and high smoke emission. To encounter this problem hydrogen was inducted by a port fueled injection system. Hydrogen is considered to be low polluting fuel and is the most promising among alternative fuel. Its clean burning characteristic and better performance attract more interest compared to other fuels. It was more active in reducing smoke emission in biodiesel. A main drawback with hydrogen fuel is the increased NO_x emission. To reduce NO_x emission, TME-ethanol blends were used in various proportions. After a keen study, it was observed that ethanol can be blended with biodiesel up to 30% in unmodified diesel engine. The present work deals with the experimental study of performance and emission characteristic of the DI diesel engine using hydrogen and TME-ethanol blends. Hydrogen and TME-ethanol blend was used to improve the brake thermal efficiency and reduction in CO, NO_x and smoke emissions.

1. Introduction

In recent years, the emphasis on reducing pollutant emissions from petroleum-based engines has necessitated the development and testing of several alternate fuels. The major pollutants from the diesel engines are NO_x (NO-Nitric Oxide and NO_2-Nitrogen dioxide) and smoke intensity (Sukjit et al., 2013; Isaac JoshuaRamesh Lalvani et al., Annamalai). In order to minimize these harmful pollutants we have to look for an alternative fuel that would not only reduce these pollutants but could prevent the emission of other pollutants like aldehydes, ketones, and SO_x (Wallner et al., 2011). The proposed alternative fuel are vegetable oils, alcohols, LPG, CNG, and hydrogen. Among these, hydrogen and vegetable oils emerge as a aspiring solution to the fall of fossil fuels, which acts as a renewable, recycleable, and promising long term fuels (Parthasarathy et al., 2013). Vegetable oils can be directly used in compression ignition engines without any modification. The primary problem associated with using pure vegetable oil as a fuel in a compression ignition engine is caused by viscosity (An et al., 2012). Transesterification is one of the peculiar technique by which the viscosity of the fuel can be reduced for implementating in compression ignition engine. In this process the vegetable oil is reacted with ethanol or methanol in the presence of a catalyst (NaOH) at 80 °C to get biodiesel (Roy et al., 2011). Mohan Raj et al. Mohan and Murugumohan Kumar (2012) conducted an experiment a study on tamanu an alternative fuel for diesel engine. They have selected methyl esters of vegetable oils are like Cotton seed, Pongamia, Rice bran and tamanu are used as a fuel in CI engine. Among these, TME shows excellent properties than other fuels. TME is nontoxic and non-edible oil. It has a higher cetane number and calorific value compared to other fuels. The properties of TME, diesel, ethanol, TMEE, and hydrogen are exposed in Table 1.

Use of biodiesel as fuel in diesel engine produces high smoke emission. To overcome this problem, hydrogen enriched air can be inducted into the engine by intake manifold (Vancoillie et al., 2011). Hydrogen can be commercially produced from electrolysis of water and by coal gasification. Several other methods such as thermo chemical decomposition of water and solar photo-electrolysis but presently hydrogen are used in the laboratory rather than commercial techniques (Gomes Antunes et al., 2009).

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Nomenclature

BP	Brake power
TME	Tamanu methyl ester
TMEE	Tamanu methyl ester ethanol blend
CNG	Compressed natural gas
LPG	Liquefied petroleum gas
lpm	liter per minute
E	Ethanol
BTE	Brake thermal efficiency
SEC	Specific energy consumption
CO	Carbon monoxide
CO_2	Carbondioxide
UBHC	Unburnt hydrocarbon
ppm	Parts per million
NO_x	Oxides of nitrogen
HRR	Heat release rate

Table 1
Properties of TME, diesel, ethanol, TMEE blends and hydrogen.

Properties	Diesel	TME	Ethanol	Hydrogen	TME90E10	TME80E20	TME70E30	ASTM Method
Flash point (°C)	72	108	16.6	–	103.41	98.84	94.27	D93
Density (g/cc)	0.86	0.905	0.789	0.083	0.891	0.886	0.887	D1298
Calorific value (kJ/kg)	44,000	41,500	26,810	119,930	40765.4	40029	39296.4	D3338
Oxygen (wt%)	0.15	13.4	34.7	–	14.78	18.2	19.6	D5291
Carbon (wt%)	86.3	76.41	52.2	–	73.7	72.1	69.4	D5291
Hydrogen (wt%)	13.22	12.64	13.1	99.6	12.67	12.74	12.85	D5291
Pour point (°C)	12	11.3	−27	5	9.285	7.37	5.455	D4539
Cetane number	45	50	8	–	47.8	45.7	43.69	D613
Viscosity at 40 °C mm^2/s	2.95	4.09	0.756	–	3.82	3.6566	3.4899	D3338
Cloud point (°C)	−2	26	37.9	−230	26.4955	27.181	27.6865	D97
Acid number mg KOH/g	0.051	48	40	–	47.5	47.1	46.6	D611

Combustion of hydrogen results in water which is a non-toxic emission. Due to this property researches are using hydrogen as an alternate fuel in internal combustion engines and also the development of fuel cell power vehicles and HEV's improving the opportunity for use in hydrogen fuel vehicles (Jeong et al., 2011). Hydrogen cannot be directly used in CI engine due to higher self-ignition temperature. But it can be used as a secondary fuel along with vegetable oil in dual fuel mode. Hydrogen is the major possible alternate fuel that can be derived from natural resource such as coal, Shale oil, and uranium (Probir Kumar and Dines, 2009; Saravanan et al., 2008). Justin Fulton et al. Justin et al. (1993) described that hydrogen is presently more expensive than the fossil fuels. It was concluded that there was a reduction of 21% CO and 33% HC emissions. Carl A Kukkonen et al. Kukkonen and Shelef (1994) has explained the technical feasibility, advances in hydrogen production, distribution, on board storage and used as fuel in internal combustion engines. Walter Peschka et al. Walter and William (1993) hydrogen is being used as fuel in SI engines around the world due to its has high octane rating. But for using it in a diesel engine requires a source of ignition since it cannot burn at end of compression temperatures of a diesel engine. The auto ignition temperature of hydrogen is around 900 K. Das LM et al. Das (1996) has reported that fuel induction technique (FIT) does play a important role in obtaining smooth engine operation. It has been concluded that fuel induction is one of the promising techniques for the use of hydrogen in CI engine. Li Jingding et al. Jingding et al. (1985) described the mechanism of backfire in hydrogen fuel engine and its control. Various methods for controlling back fire were verified from the viewpoint of thermal explosion theory. It has been stated that cooling high temperature residual gases, and hot deposits in the combustion chamber during the opening of the intake value can reduce backfire. In addition, NO_x emission are a major problem with hydrogen induction. Ethanol blend with in biodiesel offers greater potential for reducing NO_x emission (Lata et al., 2012; Boretti, 2011). Since ethanol has a very high latent heat of vaporization, it helps to reduce the peak temperature during combustion. It results in the reduction of NO_x emission. Ethanol can be produced from crops, like corn (De-gang et al., 2005). De-gang et al. Wu et al. (2011) conducted experiments on a diesel engine using neat diesel fuel, E5, E10, E15, and E20 of ethanol diesel blended fuels. The results indicated that smoke, CO, and NO_x emission decreased with ethanol diesel blended fuel, especially with E10 and E15. Finally, it was concluded that hydrogen could be used to reduce smoke and other emission in biodiesel as a fuel in diesel engines using dual mode of operation. The problem of oxides of nitrogen emissions with hydrogen induction can be encountered by adding ethanol with biodiesel.

2. Experimental setup

The objective of the present work is to improve the performance and reduce emission levels using hydrogen and TME-ethanol blends. The specifications of the engine are given in Table 2. The engine was coupled to an electrical dynamometer with resistance loading. The engine was mounted on the engine bed with suitable connections for lubrication and cooling water supply. The fuel was supplied from a fuel tank at a height of 2 m above the ground and the flow is by means of gravity. The fuel consumption rate was measured by noting the time taken from a known volume of fuel flow. Fig. 1 shows the schematic diagram of the experimental setup. Emission parametes (CO, CO_2, NO_x, UBHC) were measured by using Crypton 290 EN2 five gas analyser and smoke emission was measured with aid of AVL 437. The specification of both emission measuring instruments are given in Tables 3 and 4. Hydrogen gas stored in a high-pressure cylinder at 160 bar was

Table 2
Engine specifications.

Manufacturer	Kirloskar oil engines ltd.
Type of engine	4-stroke, single cylinder, diesel engine
Bore	87.5 mm
Stroke	110 mm
Speed	1500 rpm
Rated power	5.7 kW@1500 rpm
Compression ratio	17.5: 1
Injection pressure	200–205 bar

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