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An experimental study on combustion and emission analysis of four cylinder 4-stroke gasoline engine using pure hydrogen and LPG at idle condition

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Abstract

Fluctuation in oil prices and stricter exhaust emission norms were the main reasons wakening every researcher to search for suitable and feasible alternative fuels for automotive use. Among the available option gaseous fuels find their best position because of their compatible physical-chemical properties and ecofriendly nature than present fossil fuels. Hydrogen's combustion properties like high energy content, high heating value, wide range of flammability and low ignition energy with almost least toxic emissions are favorable to use in an IC engine as an alternative fuel. Liquid petroleum gas (LPG) has lower carbon content, higher calorific value, octane number and flame propagation speed will improve the emission results compared to gasoline fuel.

This paper describes an experimental results carried out to evaluate the combustion and emission performance of a Maruti Suzuki make, spark ignited four cylinders, four stroke engines at idle condition by using pure hydrogen, LPG and gasoline. The engine was adjoined with Electronic Control Unit (ECU) assisting hydrogen and LPG injector system keeping gasoline line unchanged. Tests were carried out by using compressed hydrogen gas regulated by two stage pressure reduction from cylinder to atmospheric value and by using vaporizer pressure for LPG. For comparison engine was run first by gasoline and then by pure hydrogen and LPG. Study revealed that there was increment of 13% cylinder pressure for pure hydrogen and decrement of 4.5% cylinder pressure for LPG when compared to gasoline.

The burn duration for pure hydrogen, LPG and gasoline were found to be increasing respectively which infers that hydrogen has very short combustion duration and gasoline higher. It was observed that toxic emissions like Carbon monoxide (CO), Hydrocarbons (HC) and Oxides of Nitrogen (NO_x) were improved for pure hydrogen than LPG and gasoline.

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1. Introduction and history

Sprawling use of automotive for transportation, crisis of crude oil and its limited resources, alarming trend of environmental pollution and its safeguarding features, sterner emission control norms have created interest among several researchers to look up practical alternative fuels for automotive use. Some of the alternative fuels suited for spark ignition (SI) engines have been known since the inception of the internal combustion (IC) engines. Those can be grouped as gasoline, alcohols and gaseous fuels [1]. Universally gaseous fuels are favorable substitute fuels due to their high calorific value, high Hydrogen to carbon (H/C) ratio and least polluting exhaust emissions [2]. In the last few decades, gaseous fuels such as natural gas (NG), Liquid petroleum gas (LPG), and hydrogen have been extensively studied in spark ignited research engines and favorable results have been obtained from the efficiency and emission point of view [3-10]. These outcomes have also supplemented by various research works [11-17].

LPG is extracted from crude oil during refining process of petroleum and from natural gas alternatively it is also obtained from oil/gas mining as a byproduct [18-19]. Though LPG is rich in propane but it also contains butane, propene, iso-butane and n-butane in different proportions [20-21]. It is heavier than air, has higher latent heat of vaporization, low carbon content, cheaper and clean burning fuel than gasoline and easily can be adopted in SI engines [22].

Hydrogen is available abundantly in the universe in compound form, not in free state. It is fortunate otherwise it would have reacted rapidly with other elements. Hydrogen has to be extracted either from higher energy fossil fuels or lower energy water [23-24]. Hydrogen is considered to be one of the superior alternative fuels for SI engines because of its specific and most desired properties, such as wide flammable range, higher diffusivity, high flame speed, lower ignition energy etc. [14]. Properties of hydrogen, gasoline, and LPG are shown in table 1 for further reference.

Table1. Properties of hydrogen, gasoline, and LPG [25-27]

Property	Hydrogen	Gasoline	LPG
Density (kg/m ³) at 27°C and 1 atm	0.082	730	2.26
Lower heating value (MJ/kg)	120	44.8	45.7
Higher heating value (MJ/kg)	141.9	48.3	50.15
Minimum quenching distance (mm)	0.64	2.0	1.73
Minimum ignition energy(mJ)	0.02	0.24	0.26
Flammability limits in air (vol%)	4-75	1.3-7.1	2.15-9.6
Stoichiometric air-to-fuel ratio (kg/kg)	34.2	14.6	15.5
Flame Temp (°C)	2207	2307	1960
Auto ignition Temperature (°C)	585	230-480	405-450
Octane number	130	87	103-105
Flame velocity (m/s)	2.65-3.25	0.3-0.5	0.3825

Idle speed is the necessary operating speed of the engine which defines its lowest speed or speed at which throttle is closed. At idle speed, the engine lacks the inertia to smooth out the lag between the operating cycles. If the idle speed is too low engine will stall and will waste fuel when it is high. An idle condition is substantial for automobiles and has great influence on an exhaust emission; fuel consumption and vehicles comfort. Nowadays vehicle congestion at traffic conditions in idle situation is a common problem and known that combustion & emissions characteristics are different for idle and normal conditions of the engine. Many researchers have sight seen the results of idle performance for different engines which are briefly summarized below

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