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EXPERIMENTAL INVESTIGATION OF VARIOUS HYDROGEN KNOCK LIMIT EXTENSION STRATEGIES ON A HYDROGEN-GASOLINE DUAL FUEL SPARK IGNITION ENGINE

by

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Abstract

Hydrogen is a clean and carbon free substitute with the ability to significantly cut down the harmful emissions while enhancing the energy efficiency of internal combustion engines (ICE) typically powered by conventional fossil fuels. Hydrogen is the most abundant element which can be easily obtained from sources like water and biomass. The wide flammability range and high laminar flame velocity outstands hydrogen from other fuels. However, hydrogen fueled engines are more prone to abnormal combustion like knock and backfire due to its low ignition energy and high adiabatic flame temperature. To avoid backfire, several well-developed approaches have been reported. Unlike backfire, combustion knocks are more severe and difficult to control. Thus, a study on extending the hydrogen on extending the hydrogen knock limit is of great importance.

The main focus of this thesis is to investigate various strategies that helps in extending hydrogen fraction while avoiding the engine knock in spark ignition engine operating under hydrogen–gasoline dual fuel combustion where conventional gasoline is replaced drastically by hydrogen. The first part of the thesis investigates the hydrogen–gasoline combustion in a Ricardo single cylinder SI engine with hydrogen manifold induction and gasoline direct injection. A range of experimental trials were conducted to investigate the original knock limit, performance, combustion and emissions under various engine speed and gasoline injection quantity. Hydrogen exhibited superior results than pure gasoline which are more pronounced at low engine speed with the highest brake thermal efficiency of 27.48% at 1000 rpm. Apart from that, the highest gasoline injection quantity showed the least cyclic variation which is mainly due to the concentration of gasoline near the vicinity of spark plug. The result showed that at default configuration for the best combination (1000 rpm and 6 mg gasoline) a hydrogen knock limit of 8 LPM was achieved. Next a comparison study between pure gasoline and hydrogen–gasoline mixture knock was conducted. The outcomes exhibited that the hydrogen enrichment results in severe knock. The combustion knock are usually inherited with high cylinder pressure and abnormal heat release rate. The heat release rate at knocking conditions were 151.2 and 128.53 J/deg for the 25% and 12.5% hydrogen flow rate compared to 86.86 J/deg for pure gasoline.

Following this, several methods that can be implemented to an existing engine on extending the hydrogen knock limit was investigated. To facilitate these studies, change in spark timing, intake air temperature and pressure, and dilution with CO2 gas and fuels possessing high latent heat of vaporization were adopted. A retardation in spark timing showed an increased hydrogen flow rate. The result showed that a hydrogen flow rate of 14 LPM was achieved from the original limit of 8 LPM when the spark timing retarded from 12° CA to 4° CA BTDC. This is due to the extension of combustion process to the expansion stroke with reduced the cylinder pressure and temperature. Moreover, a change in intake air pressure and temperature also facilitated the extension in hydrogen knock limit. An increase in intake air pressure and decrease in the intake air temperature allowed the extension of hydrogen knock limit. A hydrogen flow rate of 18 LPM was achieved at an intake air pressure of 112 kPa at 4° CA BTDC. Furthermore, hydrogen knock limit was influenced greatly by the addition of ethanol and methanol fuels. The highest hydrogen flow rate of 16 and 18 LPM was obtained for 50% volume proportions of ethanol and methanol, respectively. This increment was due to the high latent heat of vaporization of alcohol which provides a charge cooling effect during combustion. Apart from these strategies, dilution of combustible mixture with CO2 gas also extended the hydrogen knock limit. A maximum hydrogen flow rate of 16 LPM was achieved which can be attributed to the high heat capacity and inert nature of CO2 gas.

Further, the research outcomes can be extended to wide applications in the field of automotive and aerospace. These approaches can be implemented on jet, stationery and gas engines with less dependency on fossil fuel-based products.

Keywords: *Hydrogen–gasoline, dual fuel, knock limit, abnormal combustion, spark timing, ethanol, methanol.*