A NUMERICAL STUDY ON THE EFFECT OF GASOLINE-HYDROGEN FUEL BLEND ON ENGINE POWER AND TORQUE

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AWARD FOR DEGREE

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Report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Mechanical Engineering.

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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Date: 6 DISEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

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ABSTRACT

This report was about the effect of gasoline-hydrogen fuel blend on engine power and torque. The experiment had been done by using different ratios of gasoline and hydrogen fuel. In this simulation, the ratio of gasoline and hydrogen were varied in order to analyze the power and torque of the engine. The engine modelling was drawn by GT-Power software and was analyzed by GT-Post software. The ratios that had been used in this analysis were by increment of 10% for hydrogen fuel and decrement of 10% for gasoline fuel until both fuel reached 50%. The engine that has been used was a single cylinder engine with four stroke cycle, by using SI-inject. The values for the power and torque of the engine is increased by the increasing of fuel ratio at both engine speeds. The values of engine power were increasing even though we run it at 3000 rpm and 6000 rpm but as for the torque, the values were higher at 3000 rpm but decreasing at 6000 rpm.

ABSTRAK

Laporan ini membentangkan tentang pengaruh campuran petrol dan minyak hidrogen terhadap kelancaran enjin kereta dari segi kuasa dan tenaga putaran pada kelajuan enjin yang sederhana dan tinggi. Ujian ini telah dijalankan dengan menggunakan nisbah minyak yang berbeza pada lain-lain masa. Model enjin ini dilukiskan dengan menggunakan perisian GT-Power manakala akan dianalisis dengan menggunakan perisian GT-Post. Dalam simulasi ini, nisbah yang akan digunakan ialah dengan menggunakan kenaikan sebanyak 10% bagi minyak hidrogen dan penurunan sebanyak 10% bagi petrol sehingga kedua-duanya mencapai 50%. Model enjin yang digunakan dalam perisian ini ialah enjin satu silinder, empat strok proses dengan menggunakan penyalaan pencucuh. Selepas dianalisis, didapati nilai kuasa dan tenaga putaran semakin meningkat pada kedua-dua kelajuan enjin. Nilai kuasa yang didapati ketika kelajuan enjin 3000 revolusi per minit akan bertambah apabila kelajuan enjin ditinggikan sehigga 6000 revolusi per minit, tetapi sebaliknya terjadi kepada tenaga putaran. Nilai tenaga putaran pada 3000 revolusi per minit didapati lebih tinggi berbanding nilai tenaga putaran pada 6000 revolusi per minit.

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λ	Air fuel ratio
Φ	Equivalence ratio

LIST OF ABBREVIATIONS

CO_2	Carbon Dioxide
ICE	Internal Combustion Engine
SI	Spark Ignition
NOx	Nitrogen Dioxide
HC	Hydrocarbon
HHV	Higher Heating Value
LHV	Lower Heating Value

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The use of hydrogen as a fuel for internal combustion engines either directly or indirectly is not new. Experiments have been done decades before to investigate the effectiveness of using hydrogen as a fuel. However, due to certain disadvantages, its progress to become the fuel of the future is slow. The depleting resources of fuel in the world today as well as the understanding of the need of the world environment requires the search for other types of fuel sources that may be renewed if possible. Fuels such as natural gas, liquid petroleum gas (LPG) and hydrogen are some of the alternative fuels to traditional ones that are fossil based such as diesel and gasoline. These conventional fuels have major disadvantage with regards to their exhaust emissions of nitrogen oxides (NOx), unburned hydrocarbons (UHC), carbon dioxides (CO_2) and particulate matter which are hazardous to humans and environment alike (R. Adnan, 2008)

The greenhouse effect is also one of the aftermaths from these gaseous emissions. The number of vehicles on the road increases every day. With each vehicle, there exist a proportion of exhaust emissions, which consists of particles that are harmful to the environment and people. With the increase in numbers of vehicles, more fuel would be required to cater for the need of consumers. However, the conventional fuel for the engine such as diesel and gasoline are fossil based fuel and as such is not renewable. The availability of these fuels is fast diminishing and an alternative comparable fuel must be discovered quickly to avoid any possible future problems. Such a fuel should also be able to tackle the existing environmental problems of fossil fuel. Hydrogen is a very good alternative as a fuel, as it can never diminish. It is readily available and has no problem of excessive environment pollution. Hydrogen can be obtained from water and is practically carbon-free. The only known pollution derived from the combustion of hydrogen is NOx. This paper tries to predict the effect of gasoline-hydrogen fuel blend on engine in the perspective of its performance (power and torque (R. Adnan, 2008).

1.2 PROBLEM STATEMENT

The performance of the engine depends on so many factors and one of it is the type of fuel we use for the engine. Nowadays, there are so many type of fuel that been used all around the world that effect the engine and each of it have their own advantages and disadvantages. But the best fuel for the engine still not exist and there are too many space for improvement for researcher to find the one fuel that will give a lot of benefits to the performance of the engine such as to make sure the performance of the engine at the high level but safe to be use.

The world also aware with many type of fuel used all around the world that might affect the environment and this lead to searching for the alternative fuel. Hydrogen is a very good alternative as a fuel, as it can never diminish. It is readily available and has no problem of excessive environment pollution.

1.3 OBJECTIVE

The objective of this project is as follows:-

a) To investigate the effect of the gasoline-hydrogen blended fuels on engine power and torque.
b) To quantify engine performance by the result from the GT Power software.
c) To find the best fuel for the engine and give benefits for the mankind.

1.4 SCOPE OF PROJECT

The identified scope of this project is as follows:-

a) Simulate the engine model with the GT-Power software
b) The software will be able to generate data for engine power and torque
c) Study on the four strokes cycle, single cylinder engine
d) The fuel use will be hydrogen-gasoline blend

1.5 PROJECT IMPORTANCE

The benefits that could gain from this project are:-

a) The effect of the gasoline-hydrogen blends fuel on the engine power and torque can be determined and we can know the advantages and disadvantages of this fuel.
b) This can give knowledge for the further study of the other researcher if it does not achieve the objective.
c) To get the best solution for the best fuel in order to achieve the high performance of the engine.

CHAPTER 2

LITERATURE REVIEW

2.1 INRODUCTION OF HYDROGEN

Hydrogen means “water creator”, it was identified as a base material by Cavendish (1731-1810). At room temperature and under normal pressure, hydrogen is a colourless, odourless and non-poisonous gas which is lighter than air and helium. Hydrogen burns with a pale blue, almost invisible flame. At temperatures under -253 ºC hydrogen is in a liquid state (Bellona Report, 2002).

Hydrogen is the most common base material in the universe and is the main substance found in the sun and the stars. On earth practically all hydrogen is in a compound form with other elements. It reacts very readily with oxygen to create water. The water molecule consists of two hydrogen atoms and one oxygen atom. The oceans of the world therefore make up a huge storeroom of hydrogen. Hydrogen is also an important part of all organic matter. This includes vegetable, animal, and fossil matter. In the environment, hydrogen can be freely found in volcanic gasses, but its lightness allows it to escape beyond the earth’s gravitational forces (Bellona Report, 2002).

Table 2.1: Properties of Hydrogen

Atomic Number	Atomic Symbol	Atomic Weight	Electron Configuration	Atomic Radius	Melting Point	Boiling Point	Oxidation States
1	H	1.0079	$1s^1$	78 pm	- 259.34 C	-252.87 C	1, -1

2.2 HISTORY OF HYDROGEN

Hydrogen was prepared many years before it was recognized as a distinct substance by Henry Cavendish in 1776 but he called it as "inflammable air". He described the density of inflammable air, which formed water on combustion, in a 1766 paper "On Factitious Airs" but there is also one more important person that is Antoine Lavoisier. He is the man that stated the first version of the law of conservation of mass, recognized and named hydrogen (1783).

Industrial production is mainly from the steam reforming of natural gas, and less often from more energy-intensive hydrogen production methods like the electrolysis of water. Most hydrogen is employed near its production site, with the two largest uses being fossil fuel processing and ammonia production, mostly for the fertilizer market.

Hydrogen is a concern in metallurgy as it can embrittle many metals, complicating the design of pipelines and storage tanks.

2.3 ADVANTAGES OF HYDROGEN

Hydrogen can be said as the most alternative of the alternative fuel because if it is made by electrolysis of water using electricity from a nonpolluting source like wind or solar power, then no pollutants of any kind are generated by burning it in an internal combustion engine except for trace amounts of nitrogen oxides, and if it is used in a fuel cell then even these disappear. This shows how much that hydrogen fuel can improve the environment. Furthermore, no greenhouse gases are generated because there's no carbon in the fuel. This can be showed by the relevant fact; when hydrogen is burned in air the main product is water. Some nitrogen compounds may also be produced and may have to be controlled. Should greenhouse warming turn out to be an important problem, the key advantage of hydrogen is that carbon dioxide (CO_2) is not produced when hydrogen is burned.

Having wide flammability limits compared to other gases such as gasoline and methane also is one of the advantages of hydrogen as an alternative to petroleum fuels.

It means that the possible mixture compositions for ignition and flame propagation are very wide for this gas. This also means that the load can be controlled by the air to fuel ratio, and wide open throttling engine will resulting in high efficiency of engine (Lanz, 2001 and Sierens, 2005). Figure 2.1 below shows the ranges of flammability of comparative fuels at atmospheric temperature and as been told, we can see that hydrogen has the highest wide flammability which is 75% compared to other fuels.

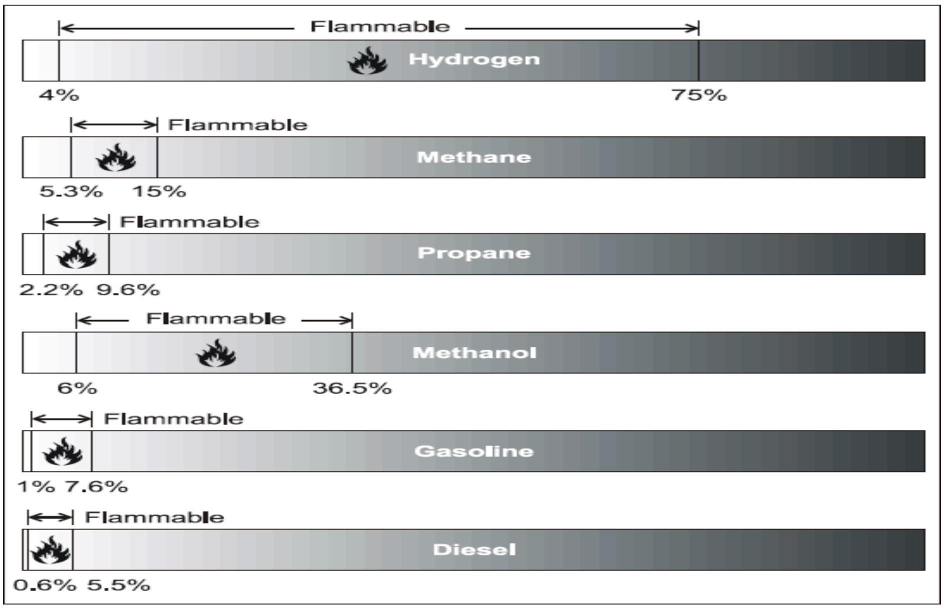

Figure 2.1: Flammability Ranges of Comparative Fuels at Atmospheric Temperature

Source: Lanz (2001)

Using hydrogen to store energy from a nonpolluting, renewable source would result in a truly unlimited supply of clean fuel. The advantage of using hydrogen to store energy rather than a battery pack is that a hydrogen tank can be refilled in minutes rather than recharged in hours, and it takes less space and weight to store enough hydrogen to drive a given distance on a single refueling than it does to carry enough battery capacity to go the same distance on a single recharging. The battery-electric drive train uses energy more efficiently, and can handle the vast majority of daily commute-and-errands driving that people do, but for long trips hydrogen could prove to be a lot more convenient. Hydrogen has the potential to run a fuel-cell engine with greater efficiency over an internal combustion engine. The same amount of hydrogen will take a fuel-cell car at least twice as far as a car running on gasoline.

Since hydrogen is not available in significant quantities in nature in pure form, the main present way of getting hydrogen is steam methane reforming, and this will probably remain the most economical way as long as methane is available cheaply and in large quantities, and hydrogen is required only in small quantities. When the price of methane goes up to more than three times its present price because of scarcity, hydrogen will be obtained by splitting water H_2O into hydrogen H_2 and oxygen O_2 by using electrolysis. The chemical reaction is written:

$$2H_2O + \text{energy} \Rightarrow 2H_2 + O_2. \qquad (2.1)$$

Energy content of fuel is important in determining the power produced by an engine. Every fuel will have different energy content based on their properties. They also can liberate a fixed amount of energy when it reacts completely with oxygen to form water. This energy content is measured experimentally and is quantified by a fuel's higher heating value (HHV) and lower heating value (LHV). The difference between the HHV and the LHV is the "heat of vaporization" and represents the amount of energy required to vaporize a liquid fuel into a gaseous fuel, as well as the energy used to convert water to steam. The higher and lower heating values of comparative fuels are indicated in Table 2.2 below.

Table 2.2: Heating values of comparative fuels

Fuel	Higher Heating Value (at 25˚C and 1 atm / kJ/g)	Lower Heating Value (at 25˚C and 1 atm / kJ/g)
Hydrogen	141.86	119.93
Methane	55.53	50.02
Propane	50.36	45.60
Gasoline	47.50	44.50
Diesel	44.80	42.50
Methanol	19.96	18.05

Source: Lanz (2001)

Both the higher and lower heating values denote the amount of energy (in Btu's or Joules) for a given weight of fuel (in pounds or kilograms). Hydrogen has the highest energy-to-weight ratio of any fuel since hydrogen is the lightest element and has no heavy carbon atoms. Specifically, the amount of energy liberated during the reaction of hydrogen, on a mass basis, is about 2.5 times the heat of combustion of common hydrocarbon fuels (gasoline, diesel, methane, propane, etc.) The high energy content of hydrogen also implies that the energy of a hydrogen gas explosion is about 2.5 times that of common hydrocarbon fuels. Thus, on an equal mass basis, hydrogen gas explosions are more destructive and carry further. However, the duration of a conflagration tends to be inversely proportional to the combustive energy, so that hydrogen fires subside much more quickly than hydrocarbon fires (Lanz, 2001).

2.4 DISADVANTAGES OF HYDROGEN

Hydrogen is currently very expensive, not because it is rare but because it's difficult to generate, handle, and store, requiring bulky and heavy tanks like those for compressed natural gas (CNG) or complex insulating bottles if stored as a cryogenic liquid like liquefied natural gas (LNG). It can also be stored at moderate temperatures and pressures in a tank containing a metal-hydride absorber or carbon absorber, though these are currently very expensive. It is possible to store a hydrogen-bearing fuel like natural gas, methanol, or even gasoline aboard the vehicle and re-form it to get hydrogen as needed; this simplifies storage and refueling, but adds cost and complexity to the drive train and reduces the efficiency.

In the contact of safety issues, we can see the fact that liquid hydrogen has the ability to freeze air. There have also been reports of accidents with the fuel cell itself. Sometimes a valve will get plugged up when there is too much pressure in the cell. The only place to go is out, and the cell explodes. There is no way of knowing, yet, if this problem can be fixed, but there are many working on it. In a car accident, the tank might rupture, but the good news is the hydrogen will evaporate quickly. However, it is a more serious condition in a closed area such as a garage.

Hydrogen only has high flame speed at stoichiometric ratios, but at leaner mixtures, the flame velocity decreases significantly. Another property of hydrogen that gives it a disadvantage is that it is very low density gas. Using hydrogen in an internal combustion engine, there is a very large volume of hydrogen needed to store to give a vehicle an adequate driving range. Low density of hydrogen will also result in the energy density of a hydrogen-air mixture and thus the power output is reduced (Lanz, 2001 and White, 2006).

2.5 PREVIOUS STUDY

The technology of using hydrogen as a combustion enhancement in internal combustion engines has been researched and proven for many years. The benefits are factual and well documented and also been tested and proven both by institutions and in hundreds of practical applications in road vehicles.

In this chapter, various previous study and research will be discussed in order to be the references for the project.

In view of the excellent combustion properties of hydrogen and positive features of lean combustion, there have been many publications focusing on the performance of hydrogen-enriched engines. Andrea et al. (2004) investigated the effect of various engine speeds and equivalence ratios on combustion of a hydrogen blended gasoline engine. He carried out the experiment on a modified carburetor gasoline engine. The hydrogen and air was premixed in a specific tank before entering the cylinder. The experiment results showed that the combustion duration decreases with the increase of hydrogen blending fraction. The cyclic variation was also eased by hydrogen addition

Li et al. (1998) studied the mechanism of the toxic emissions formation processor the engine fueled with hydrogen–gasoline mixture, and validated it on a modified carburetor gasoline engine. From the experiment, he found that NOx, HC and CO emissions from the hydrogen-enriched gasoline engine were lower than the original one.

Varde (1981) carried out an experiment on a single-cylinder carburetor engine to investigate the effect of hydrogen addition on improving the engine lean operating stability. He found that flame development and propagation durations were decreased with the increase of hydrogen addition level. And the engine lean burn limit was also extended by hydrogen addition.

Dimopoulos (2008) performed a well-to-wheel assessment for a hydrogen enriched hydrogen enriched natural gas engine. He proved that green house emissions can be effectively reduced by hydrogen addition, whatever hydrogen is produced by gas reforming or electrolysis.

Ji and Wang (2009) investigated the effect of hydrogen addition on a gasoline-fueled SI engine performance at idle and stoichiometric conditions. The test results demonstrated that engine cyclic variation in indicated mean effective pressure was steadily decreased with the increase of hydrogen addition fraction. The engine indicated thermal efficiency and emissions performance were also improved after hydrogen enrichment; except for that HC and CO emissions were slightly increased when hydrogen volumetric fraction in the intake exceeded 4.88%.There are plenty of publications studying the effect of hydrogen addition on the compressed natural gas (CNG) engine performance. However, only limited studies were related to hydrogen-enriched gasoline engines and many researchers still used carburetor engines and mechanically inducted hydrogen or the premixed air–hydrogen mixtures into the intake manifolds. But such a method intensified the possibility of backfire in the intake manifolds due to the wide flammability and low ignition energy of hydrogen. Thereby, the quantitative effect of hydrogen addition on the modern electronically controlled gasoline engine combustion and emissions at lean conditions still needs to be investigated in detail.

2.6 GT- POWER

GT-POWER is the industry-standard engine simulation tool, used by all leading engine and vehicle makers and their suppliers. It is also used for ship and power-