ONE DIMENSIONAL SIMULATION OF DIESEL HYDROGEN DUAL FUEL ENGINE

BENEDICT MAURICE LOJIKIP

Thesis is submitted in fulfilment of the requirements for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering

UNIVERSITI MALAYSIA PAHANG

JUNE 2012

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report 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.

Signature :

Name of Supervisor : Professor Dr. Rosli Abu Bakar

Position : LECTURER

Date :

SECOND REVIEWER'S DECLARATION

I certify the thesis entitled "One Dimensional Simulation of Diesel Hydrogen Dual Fuel engine" is written by Benedict Maurice Lojikip. I have examined the final copy of this thesis and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature :

Name of Supervisor : Amir Abdul Razak

Position : LECTURER

Date :

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 accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name : BENEDICT MAURICE LOJIKIP

ID Number : MH08023

Date :

DEDICATION

My deepest gratitude to my family for their long term and long distance support. I am also very fortunate to have some course mates that do not even hesitate in helping me to finish this project. Their ideas, opinions and tips in various ways possible in helping me are greatly appreciated.

Thank you.

ABSTRACT

This thesis discussed the influence of diesel fuel mixture with hydrogen gas on diesel engine performance in terms of volumetric efficiency, brake efficiency, brake mean effective pressure and brake specific fuel consumption at different engine speed using different mass fraction of hydrogen gas. Engine model drawn using GT-Power and the results of the analysis will be displayed using the GT-Post. In this study, addition of hydrogen gas is by adding hydrogen mass fraction in the air mixture so the gas can be burn with diesel fuel. There are two mass fraction of hydrogen use in the analysis, 0.005% and 0.010% for each analysis. Analysis showed that the addition of hydrogen gas obtained show negative impact on engine performance. Engine performance continued to decrease with the addition of more mass fraction of hydrogen gas.

ABSTRAK

Tesis ini membincangkan pengaruh campuran minyak disel dengan gas hydrogen terhadap prestasi enjin disel dari segi kecekapan isipadu, kecekapan brek, brek min tekanan berkesan dan penggunaan bahan api pada kelajuan enjin yang berbeza dengan menggunakan jisim gas hydrogen yang berbeza. Dalam kajian ini, gas hydrogen ditambah pada udara supaya pembakaran gas hydrogen dengan minyak disel boleh berlaku. Terdapat dua jisim gas hydrogen yang ditambah dalam udara, 0.005% and 0.010% pada setiap kajian. Model enjin dilukis dengan menggunakan perisian GT-Power dan keputusan daripada analisis tersebut akan dipamerkan dengan menggunakan perisian GT-Post. Analisis kajian ini menunjukkan penambahan gas hydrogen memberi kesan negetif pada prestasi enjin. Prestasi enjin terus menurun terhadap penambahan gas hydrogen dengan jumlah yang lebih banyak lagi.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

Greek Symbol

σ	Stefan-Boltzmann Constant

Latin Extended

η_v	Volumetric Efficiency
η_{bth}	Brake Thermal Efficiency
ρ_a	The Inlet Air Density

Subscripts

bp	Brake Power
a	The Steady-state Flow of Air into the Engine
f	Mass Flow Rate of Fuel
m_{H_2}	Hydrogen Mass Fraction
m_{O_2}	Oxygen Mass Fraction
m_{N_2}	Nitrogen Mass Fraction
N	Engine Speed
n	Number of Revolution in one Cycle
V_{disp}	Displacement Volume
b	Brake Power
X_{O_2}	New Mass Fraction of Oxygen
Y_{N_2}	New Mass Fraction of Nitrogen

LIST OF ABBREVIATIONS

1D	One Dimension
3D	Three Dimensions
bmep	Brake Mean Effective Pressure
bsfc	Brake Specific Fuel Consumption
CI	Compress Ignition
CO	Carbon Monoxide
CNG	Compressed Natural Gas
EGR	Exhaust Gas Recirculation
GT	Gamma Technologies
H_2	Hydrogen Gas
H_2O	Water
LPG	Liquefied Petroleum Gas
LNG	Liquefied Natural Gas
NOx	Oxides of Nitrogen
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NRV	Non-Return Valve
OPEC	Petroleum Exporting Countries
O_2	Oxygen Gas
SOx	Sodium Oxide
SI	Spark Ignition
TDC	Top Dead Center
UBHC	Unburned or Partially Burned Hydrocarbon

CHAPTER 1

INTRODUCTION

1.1 RESEARCH INTRODUCTION

This chapter basically discuss on the hydrogen as fuel used on a diesel engine. It is well known that fossil fuels are widely used in the whole world and because of that the source of it become lesser by each year. Combustion from fossil fuel also produces poisonous gas that is harmful for the planet. The main pollutants cause from fossil fuel burn are unburned or partially burned hydrocarbon (UBHC), carbon monoxide (CO), oxides of nitrogen (NOx), smoke and particulate matter. Hence an alternative fuel with clean burning and renewable has to be develop and compatible with the engine design used nowadays. A lot of research is being carried out throughout the world to evaluate the performance, exhaust emission and combustion characteristic of the existing engines using several alternative fuels such as hydrogen, compressed natural gas (CNG), alcohols (methanol and ethanol),

Liquefied petroleum gas (LPG), biogas, producer gas, bio-diesels develop from vegetable oils, and other alternative fuel. For this study, the effect of hydrogen use as a dual fuel in diesel engine is observed. In real life, hydrogen cannot be use directly in compression ignition engine (CI) due to its higher self-ignition temperature. The self-ignition temperature of hydrogen is 858 K, so hydrogen cannot be used directly in a CI engine without a spark plug or glow plug. This makes hydrogen unsuitable as a main fuel for diesel engines. An alternative way to overcome this problem is to use hydrogen as an enrichment or induction where diesel is used as a pilot fuel for ignition. Hydrogen is mixed with air or injected in the intake manifold before entering combustion chamber. Small amount of diesel fuel as the pilot fuel is injected to promote ignition.

1.2 PROBLEM STATEMENT

The urge to find an alternative fuel has taken a major interest on researchers throughout the whole world. It is not only to reduce the rate of pollution but also a fuel that can replace the conventional fuel nowadays which is fossil fuel. The question of how long will the fossil fuel will last is a big question mark. No one knows how much oil is left that can be feasibly extracted in the whole world. Organization of the Petroleum Exporting Countries (OPEC) producers keeps it a big secret, as they don't want to disclose how much oil they have found or think they will find. Many think that the world is rapidly reaching the point where the growth in new supplies of oil cannot keep up with the pace of oil depletion. Estimate from international organisation suggest that if the world's demand continues at the present rate that oil and gas reserves may run out within some of our lifetimes. Coal is expected to last longer.

Table 1.1 Estimated length of time left for fossil fuels

Fossil fuel	Time left
Oil	50 years
Natural gas	70 years
Coal	250 years

A preparation is need to overcome the situation on fossil fuel depletion. More or less reserve fossil fuel, still one day the reserve will be dry out. Hydrogen which is known nowadays to all researchers as one of the alternative fuel that one day will replace the conventional fuel. Researchers have carried a lot of experiment on hydrogen to become fuel in a conventional engine. Not only to observed hydrogen as fuel but also the effect of using hydrogen on the environment. Conventional fuel use nowadays produce a lot of dangerous gases after combustion and harmful to the environment. Hence, a new and clean source of fuel has to replace fossil fuel.

1.3 OBJECTIVES

The studies objective is:

i. To investigate the effect of hydrogen in diesel engine.
ii. Performance of engine with and without hydrogen.

1.4 SCOPES

The main scopes of this study are:

i. Study is done base on single cylinder diesel engine.
ii. Various engine speeds is tested when hydrogen is applied.
iii. Three mass fraction of hydrogen is studied in simulation.
iv. Comparing engine performance with and without hydrogen.
v. To compare previous research done on hydrogen.

1.5 PROJECT METHODOLOGY

The project methodology is briefly described in the flow chart in Figure 1.1, project methodology can be simple describe as follow:

i. Setting up the one dimensional simulation in GT Power software
ii. Analyze the scopes by establishing minimum and maximum range of indicated variable.
iii. Compared result with different experiment.

1.6 HYPHOTESIS

Hydrogen addition in combustion will increase the engine performance and reducing the emission.

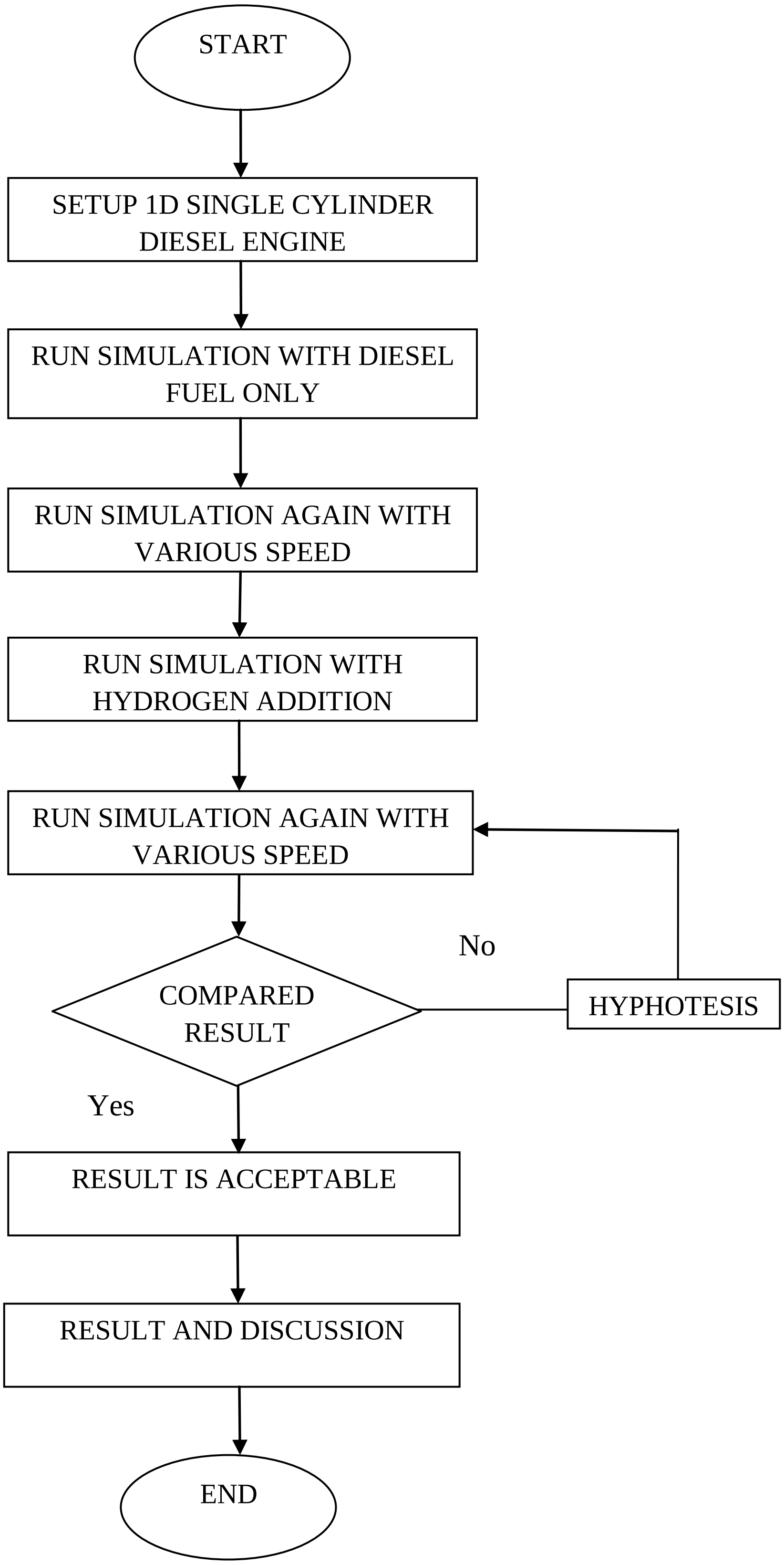

Figure 1.1: Methodology flow chart

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

During the last decade the use of alternative fuel for diesel engines has received renewed attention. The interdependence and uncertainty of petroleum-based fuel availability have created a need for investigating the possible use of alternative fuels. In recent years, the emphasis to reduce pollutant emissions from petroleum-based engines has motivated the development and testing of several alternative fuels. The main pollutants from the diesel engines are NOx (NO, nitric oxide and NO_2, nitrogen dioxide), particulate matter and smoke. To reduce these harmful pollutants a need to go for an alternative fuel that should not emit other pollutants like aldehydes, ketones and SOx (Sodium Oxide). Various fuels have been considered as substitutes for the hydrocarbon-based fuel. The alternative fuels aspiring to replace the petroleum based fuels are alcohols, LPG, CNG, hydrogen, vegetable oils, biogas, producer gas and Liquefied natural gas (LNG). Out of these, hydrogen is a long-term fuel and also it is a renewable and non-polluting fuel.

2.2 CONCEPTS OF HYDROGEN AS FUEL

Hydrogen on burning produces only water. It is non-toxic, non-odorant and also results in complete combustion (N. Saravanan et al., 2008).

$$2H_2 + O_2 \rightarrow 2H_2O \tag{2.1}$$

Due to these characteristics, research is progress to use hydrogen as an alternate fuel in internal combustion (IC) engines and also in the development of fuel cell powered vehicles. Hydrogen can be used as a sole fuel in SI engine but in CI engine hydrogen cannot be used directly due to its high self-ignition temperature, 858K compared to neat diesel, 553K (N. Saravanan et al., 2008). Therefore it can be used with diesel as mixed fuel only. Hydrogen is only one of many possible alternative fuels that can be derived from natural resources such as coal, oil shale and uranium or from renewable resources. Hydrogen can be commercially produced from electrolysis of water and also by coal gasification. Several other methods such as thermo chemical decomposition of water and solar photo- electrolysis are available, but presently used at the laboratory level rather than for commercial use.

The hydrogen fuelled vehicles that could be built with current technology are not competitive with synthetic gasoline or methanol vehicles on the basis of fuel consumption or fuel cost. However, with the development of practical and highly efficient end-use converters of hydrogen such as fuel cells, there will be a dramatic reduction in cost and improvement in efficiency of hydrogen production, safe and convenient on board storage. Flame arrestors are a set of systems for suppressing explosions inside a hydrogen-containing system. In a hydrogen engine system, flame traps have been working satisfactorily while undesirable combustion phenomenon such as backfires occurrence.

Installation of a non-return valve (NRV) in the fuel line prevents the reverse flow of gases to the engine cylinder. The concept of using hydrogen as an alternative to diesel fuel in diesel engines is not a recent one. The self ignition temperature of hydrogen is 858K. Hence hydrogen cannot be used directly in CI engine without the assistance of a spark plug or glow plug. This makes hydrogen unsuitable for a diesel engine as a sole fuel. One of the alternative methods is to adopt hydrogen-enrichment or hydrogen-induction technique, which uses diesel as a pilot fuel for ignition purpose.

2.3 DIESEL ENGINE

Part from gasoline engine, diesel engine also knows as compression ignition engine and operate 4 stroke cycles. Same as gasoline engine, performance parameters include compression ratio, swept volume, clearance volume, power output, mechanical efficiency, indicated mean effective pressure, brake mean effective pressure, specific fuel consumption and more. However, in this study performance in interest is brake mean effective pressure, brake efficiency, volumetric efficiency and brake specific fuel consumption.

Unlike gasoline engine using a spark plug for ignition, diesel engine uses a glow plug to ignite the combustion process. Thus, it is a type of an IC (ignition compression) engine which combustion of fuel is generated by fuel-air mixture compression. Diesel engine commonly used in heavy vehicles like trucks, buses and also for emergency power generation and in diesel-electric submarine. The basic principal of diesel operation is that, environmental air is suck in by vacuum force inside cylinder then intake valve is closed. Just before piston reaches the top dead centre (TDC) diesel is injected by a high pressure fuel injector. The fuel is thicker for diesel engine and burns slower than gasoline. Anyhow the piston is already moving down by the time the combustion completes so that so that the diesel engine loses some of the potential energy.

Proper control of compression ignition engine depends on two main factors, air motion and fuel injection. Plus, there are also two types of fuel injection, direct injection and indirect injection. As mention before diesel engine is a four stroke engine hence it will go through intake, compression, power and exhaust stroke. Since the study on four stroke cycle, the engine requires two rotation of crankshaft.IC engines normally have low initial capital cost, proven reliability, strong maintenance, high partial load efficiency, heat recovery capabilities, does not require external inlet fuel compression and the output not affected by higher ambient temperature.

A brief history on diesel engine, Rudolph Diesel (1858-1913) developed a theory that revolutionized the engines of his day. He envisioned an engine in which air is compressed to such a degree that there is an extreme rise in temperature. When fuel is injected into the piston chamber with this air, the fuel is ignited by the high temperature of the air, exploding it, forcing the piston down. Diesel designed his engine in response to the heavy resource consumption and inefficiency of the steam engine, which only produced 12% efficiency.

In1893, the first model ran under its own power with 26% efficiency, remarkably more than double the efficiency of the steam engines of his day. Finally, in February 1897, he ran the first diesel engine suitable for practical use, which operated at an unbelievable efficiency of 75%. This engine stood as an example of Diesel’s vision because it was fuelled by peanut oil the original biodiesel. He thought that the utilization of a biomass fuel was the real future of his engine. As a result of Diesel’s vision, compression ignited engines were powered by biomass fuel, vegetable oil, until the 1920’s and are being powered again today by biodiesel. The early diesel engines were not small enough or light enough for anything but stationary use due to the size of the fuel injection pump. They were produced primarily for industrial and shipping in the early 1900's. Ships and submarines benefited greatly from the efficiency of this new engine, which was slowly beginning to gain popularity.

By 1920’s, automotive engineers were making better progress new injection pump design allowing the metering of fuel as it entered the engine without the need of pressurized air and its accompanying tank. The engine was now small enough to be mobile and utilized in vehicles. By the year 1923, Benz of Mannheim had developed a four-cylinder diesel engine with 45 brake horse power running at 1000 rpm and it was demonstrated in a huge five ton truck. However the disadvantages of diesel engine in the early days is that the smell of fuel and diesel knock, particularly when idling. The cost of construction was also against the diesel engine, due to the problems of the injection pump and the need for heavy construction throughout the engine.

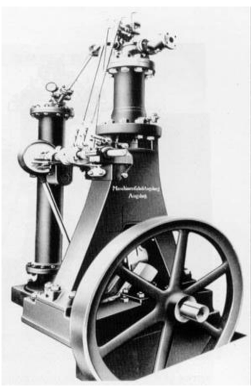

Figure 2.1: The first diesel engine (1897)

(Source: http://www.uniquecarsandparts.com.au/history_diesel.htm)

2.4 BASIC OPERATION DIESEL ENGINE WITH HYDROGEN INJECTION

One of the ways to add hydrogen gas for combustion is by injecting the hydrogen gas in intake manifold. By this way, the air can mix with hydrogen gas and undergo combustion in the cylinder the illustration can be seen in Figure 2.2.

2.4.1 Intake Stroke

During intake stroke, the piston is going down so the volume of the cylinder is getting larger. The intake valve is open, then a vacuum or pressure that less than atmospheric is created in the cylinder. Atmospheric pressure forces air into the cylinder where hydrogen is mix with air. Hydrogen gas is injected in the intake manifold and mix with air, this how hydrogen present during the combustion.

2.4.2 Compression Stroke

After intake stroke, compression stroke take place. The piston is going up so the volume of the cylinder is getting smaller. During this point, intake valve and exhaust valve are closed, and crankshaft rotates pushes the connecting rod and piston up then compresses the air-fuel mixture including hydrogen that present in the air. This increases pressure inside cylinder. Mixture is compressed into approximately 1/8 its original volume, as the mixture is compressed temperature will rise.

2.4.3 Power Stroke

Power stroke happens when compression ratio is sufficiently high to cause air-fuel mixture to ignite. During compression, both valve still closed, the flame front travels across the combustion chamber. As combustion occurs the high pressure will push the piston is pushed downward and gas expands this will turning the crankshaft and produce power. In real life, the air-fuel combustion does not occur as an explosion but rather a smooth controlled burn.

2.4.4 Exhaust Stroke

After power, the crankshaft continues to rotate and its rotation motion created pushes the connecting rod upward. The piston also travels upward contributing in cylinder volume decreases. Piston pushed the burned exhaust gasses out past the open exhaust valve and out through exhaust system and into the atmosphere.

2.5 COMBUSTION PROCESS OF DIESEL ENGINE

Further explanation on diesel combustion without the present of hydrogen gas, fuel particles injected from nozzle into the cylinder in form of high pressure is heated by high temperature and high pressure air. They ignite and burn when they begin to evaporate and are mixed with hot air. As illustrate in Figure 2.3, during the period from A to B fuel is injected from A in vapour form then heated by compressed air in the cylinder and approaches the ignition temperature. Although this period is short, the pressure does not increase suddenly because the length of this period heavily influences combustion thus it should be as short as possible. The length of this period is influenced by the ignitability of the fuel, compression pressure and temperature of the air and the injection state of the fuel.

At point B, the fuel prepared for combustion during the ignition lag period ignites at one or more locations in the gas mixture. This propagates very quickly to all parts, causing nearly simultaneous combustion. Fuel injected between B to C burns at the same time. As a result, the pressure increases suddenly. The increase in pressure is related to the quantity and the atomized state of the fuel injected during the ignition lag period. Most of the injected fuel is completely burnt by the end of this period (C).

Fuel injection continues after point C and combustion take place simultaneously because of the flames produced between B and C (flame propagation period). Therefore, the pressure change between C and D can be regulated to some extent by controlling the rate of the fuel injection.

Injection ends at point D and the burnt gas expands. Any fuel that has not burnt completely burns during this period of expansion. The period after point D is called the post-combustion period. If his period is too long, the exhaust temperature becomes too high and the thermal efficiency is lowered. Therefore, this period must be short. Combustion during this period is heavily influenced by the size and distribution of the fuel particles and their contact with the air.

Thus, combustion can be divided into four periods. The ignition lag period and the flame propagation period can be regarded as a preparatory period for the direct combustion period. Therefore, the initial injection pressure of the nozzle, the state of atomization, the compression pressure and injection timing are important maintenance items for diesel engines.

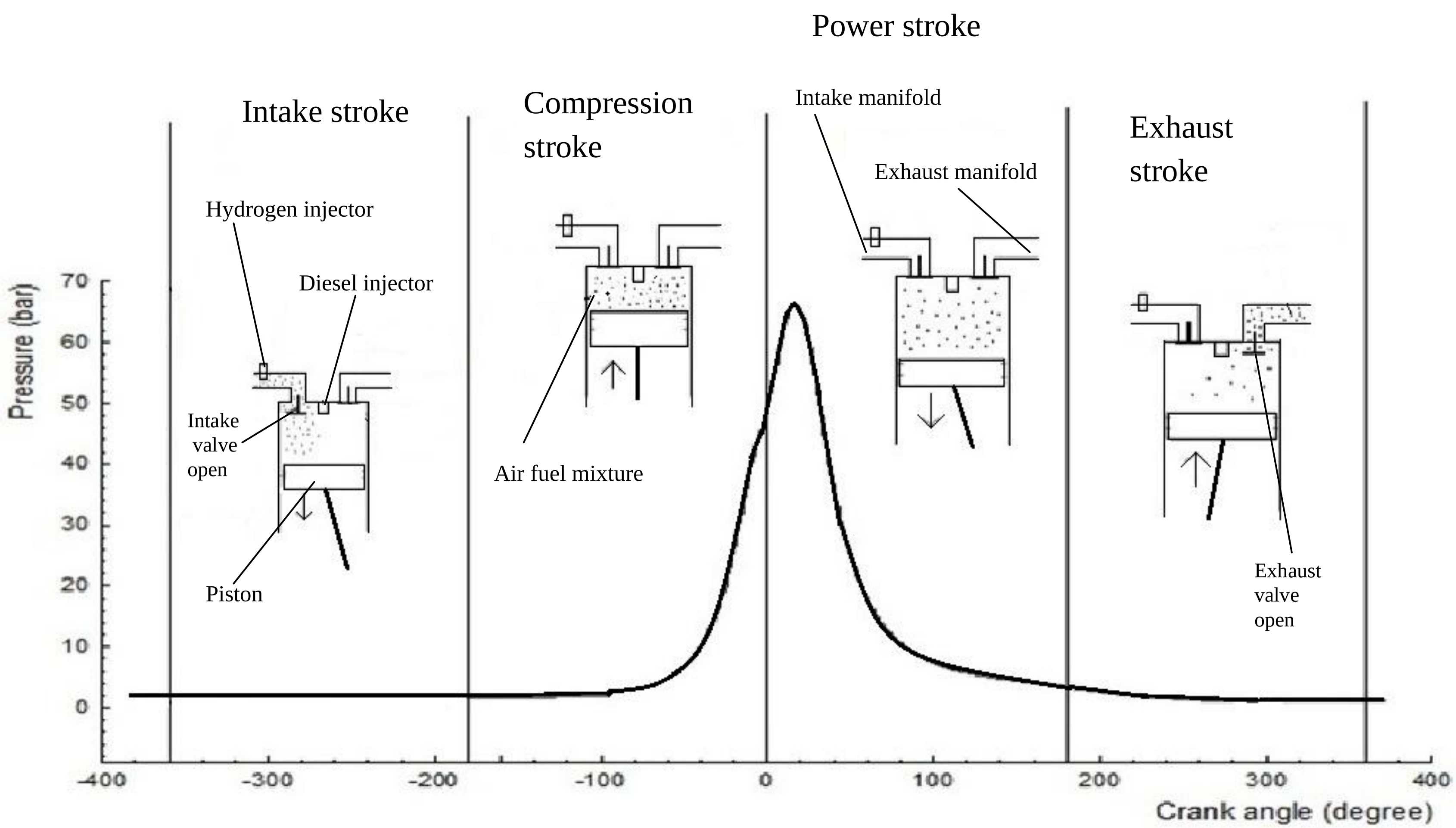

Figure 2.2: Diesel engine operation with hydrogen gas mixture

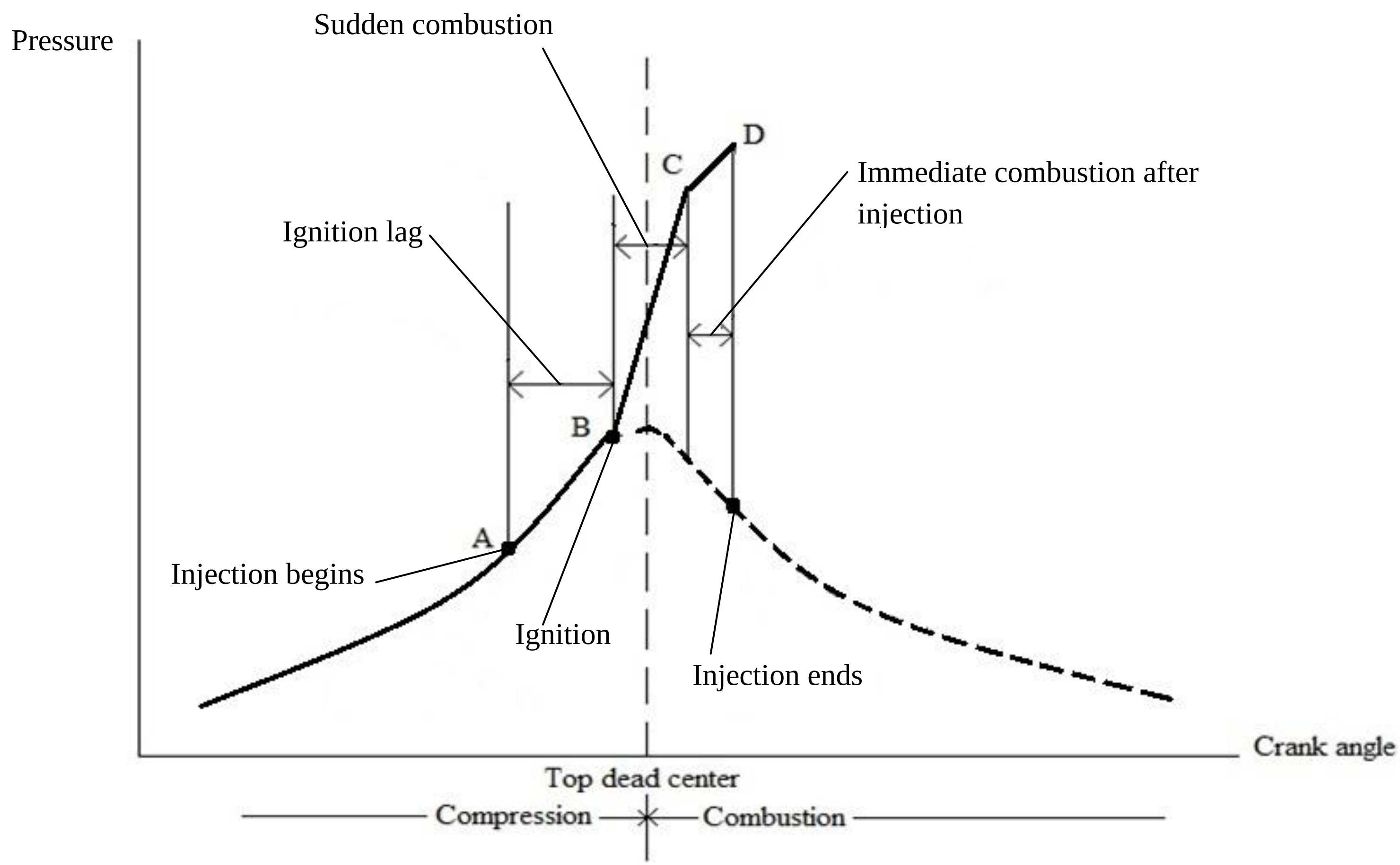

Figure 2.3: Combustion process of diesel engine

2.6 HYDROGEN

Before progressing further, it is worthwhile considering the basic nature of hydrogen, its uses and why it has emerged as the seemingly ideal solution to all our fuel requirements for vehicles in the 21st century. Hydrogen is plentiful, as it is the world's most abundant element, however it does not exist naturally in a useful form. It is a very flexible energy carrier / fuel, because of the many different ways that hydrogen can be produced, converted and used. It makes the definition of hydrogen as an energy carrier particularly appropriate.

Hydrogen is a gas at ambient temperatures and atmospheric pressure, It is colourless, odourless and non toxic and non carcinogenic. It is a highly reactive element, combining readily with carbon or oxygen, as well as other elements. Unlike other fuels it does not need to be mined. Consequently it can be produced wherever there is a source of hydrogen atoms. The two most common ways of extracting hydrogen is from hydrocarbon fluids in the form of CnH2n, (where n = the number of atoms, eg: methane = CH4, etc.) and water H2O. In 2005, these two processes accounted for nearly all hydrogen produced, at 96% and 3.9% respectively (Lemus RG and Martínez Duart JM, 2010).

One of the key properties of hydrogen is that it is a very light gas with a molecular weight of 2.02 grams/mole and a relative density compared with air of 0.07. This presents two practical problems with hydrogen systems. Firstly, having a low density makes it difficult to store large amounts in gaseous state without large storage systems. Secondly the gas is particularly prone to leakage from storage systems either through joints or at the molecular level, permeating through pipe work and storage vessels under certain conditions (e.g.: extremely high pressure).

It is flammable over a much wider range of concentrations compared with other fuels and it burns with an invisible flame, both of which present additional safety issues compared to a hydrocarbon fuel. Hydrogen liquefies at -253℃ which are at the extreme of cryogenic temperatures. This presents difficulties with both the selection of storage materials and insulation requirements to prevent heat gain to the system and hence losses due to boil off. Hydrogen also requires significant amounts of energy to liquefy. Safety concerns are mainly related to issues associated with handling of cryogenic fluids and the potential release of flammable gas clouds due to boil off of the liquid hydrogen. For further information on the properties of hydrogen refer to Appendix 1. A basic understanding of the properties of hydrogen has been necessary during the modelling phase of this research. Some properties, such as flammability etc. are already understood and addressed in the current hydrocarbon energy system for transport, but there are perhaps three properties of hydrogen that differentiate it from other sources of energy. These are;

i. Cryogenic temperature in liquid state
ii. Relatively low density in gaseous state
iii. High energy value by mass (MJ/kg) compared with other hydrocarbons

Hydrogen as a fuel has been around for a considerable time. First discovered in 1766 when Henry Cavendish recognised a new substance which he named “inflammable air”, later named by Antoine Lavoisier as “hydrogen” in 1783 (Hoffmann P, 2002). In 1898, James Dewar first liquefied hydrogen (Krasae-in S et al., 2010). Another key date in the history of hydrogen as a substance was the Hindenburg air ship which crashed in 1937, bringing hydrogen and its potential danger as a substance into public perception (Boyle G et al., 2003).

The first hydrogen fuel cell was developed by Sir William Grove in 1839, almost 170 years ago, although credit for the first practical hydrogen / air fuel cell is attributed to Francis Bacon in 1959 (The Hydrogen Association, 2009). In 1807 Francois de Rivaz invented an internal combustion engine which ran on a mixture of hydrogen and oxygen (Verhelst S and Wallner T, 2009). It wasn’t until much later (1882) that petrol was used as a fuel when Daimler and Maybach developed an Otto cycle internal combustion engine to run on petrol (Boyle G et al., 2003). Yet despite this relatively long history as both a fuel and use in vehicles, hydrogen and fuel cells in particular, the uptake of hydrogen vehicles is a fairly recent phenomenon.

There are a number of possible factors why hydrogen was not the ultimate choice for fuel for vehicles and why hydrocarbons took over, possibly due to the difficulties of producing, handling and storing hydrogen. Certainly technology has changed in that time, but perhaps the criteria for judging success and failure, such as global climate change, energy shortage and energy security have also changed. It is unlikely that any of these factors were considered two hundred years ago.

Internal combustion engines have been in use for more than a century and have undergone tremendous changes in their design, materials used and operating characteristics. Diesel engine is the most efficient type of internal combustion engines (Haroun A.K. Shahad and Nabeel Abdul Hadi,. 2011). In past few decades research efforts have been focused largely on better engine design from the perspective of reducing pollutants emission without sacrificing performance and fuel economy. Many researchers have been directed towards the development of alternative fuels to achieve this goal. Among the various probable alternative fuels, hydrogen is found to be the most promising due to its clean burning and better combustion properties.

Hydrogen has very low density. This results in two problems when used in an internal combustion engine. Firstly, a very large volume is necessary to store enough hydrogen to give a vehicle an adequate driving range. Secondly, the energy density of a hydrogen-air mixture, and hence the power output is reduced.

In general, it is desirable to have maximum volumetric efficiency for engine (M.M. Rahman et al., 2009). The importance of volumetric efficiency is more critical for hydrogen engines because of the hydrogen fuel displaces large amount of incoming air due to its low density (Probir Kumar Bose et al., 2009). This reason reduces the volumetric efficiency to high extent. A stoichiometric mixture of hydrogen and air consists of approximately 30% hydrogen by volume

Air mixture makes it possible to adopt internal mixture formation as well as external mixture formation techniques for engine system configuration. Ultra lean operation of a hydrogen engine has been made possible and the system is reported to have markedly reduced the levels of nitrogen oxides (M.K. Mohammed et al., 2009). Such low levels of nitric oxide emission can’t be met with hydrocarbon fuels because of their narrower flammability limits and lower flame speeds.

The unsteady hydrogen-air combustion, as characterized in internal combustion engines, does not differ basically in principle from the combustion of hydrocarbon fuels. The resultant effects that vividly manifest themselves arise mainly from combustion properties such as flammability range and flame propagation speed.

Apart from producing negligibly low levels of nitric oxide emissions depending upon the operating conditions, all other pollutants which come out of the tail pipe of a hydrocarbon fuelled engine (such as carbon monoxide, aliphatic and cyclic hydrocarbons) are intrinsically absent in a hydrogen engine (M.K. Mohammed et al., 2009). There are reports of traces of H_2O, formed which often get disintegrated in the exhaust system by surface reaction.

Another similar experimental study on hydrogen effect base on emission, where as inducing hydrogen from intake manifold into the cylinder of a diesel engine then injecting light oil directly inside the cylinder. Result show that hydrogen induction reduced smoke, CO, CO_2, NO_X while the brake thermal efficiency was slightly reduced (Tomita Eiji et al., 2010).

2.7 COMBUSTIVE PROPERTIES OF HYDROGEN

To make sure hydrogen gas is suitable for combustion in engine diesel, some properties of hydrogen gas that contribute to combustion is as explained below;

2.7.1 Wide range of flammability

Wide range of flammability is the range of a concentration of a gas or vapour that will burn (or explode) if an ignition source is introduced. This shows that hydrogen is extremely flammable with its range of flammability from 4% to 75% by volume. Plus, because of its high flammability hydrogen can operate in leaner (higher air to fuel mass ratio) combustion.

2.7.2 Low ignition energy

Due to hydrogen low ignition energy, these factor contributing on hydrogen prone to pre-ignition. Pre-ignition leads to harmful flashbacks in intake manifold and chamber because of “hot-spot”.

2.7.3 Very low density

Hydrogen has very low density and because of that liquid hydrogen weight less than petroleum based fuels. Density of hydrogen in gaseous state is 0.0899 grams per litre (air is 1.4 times as dense). While in liquid phase, the density is 70.99 grams per litre. This explained that hydrogen has the highest energy-to-weight ratio than other fuels. 1kg of hydrogen has the same amount of energy as 2.1kg of natural gas or 2.8kg of gasoline. The disadvantage is that hydrogen needs four times the volume for a given amount of energy

2.7.4 High diffusivity

By having high diffusivity, hydrogen can easily dissolve in air and more easily than gasoline and diesel. Therefore, hydrogen can undergo a uniform mixture of fuel and air.

2.8 PERFORMANCE PARAMETERS

The main focus on performance characteristic that can be measured how reliable is hydrogen as fuel is:

2.8.1 Volumetric Efficiency

Volumetric efficiency is used as an overall measure of a four stroke cycle engine and its intake and exhaust system as an air pumping device. The equation use for volumetric efficiency is expressed as equation (2.2):

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_{disp} N/n} \qquad (2.2)$$

where;

ρ_a	; the inlet air density
$\dot{m}_a$	; the steady-state flow of air into the engine
V_{disp}	; displacement volume
N	; engine speed
n	; number of revolution in one cycle

2.8.2 Brake Efficiency

Brake thermal efficiency (η_{bth}) is the ratio of energy in the brake power, (*bp*), to the input fuel energy in appropriate units.

$$\eta_{bth} = \frac{bp}{Mass\ of\ fuels\ x\ calorific\ \ value\ \ of\ fuel} \qquad (2.3)$$

2.8.3 Brake Mean Effective Pressure

Mean effective pressure ($bmep$) is a good parameter for comparing engines with regard to design or output because it is independent of both engine size and speed. If brake work (W_b) is used, brake mean effective pressure is obtained:

$$bmep = W_b / \Delta v \quad (2.4)$$

Where;

Δv ; volume displacement

2.8.4 Brake Specific Fuel Consumption

Brake specific fuel consumption (*bsfc*) indicates the mass flow rate of fuel ($\dot{m}_f$) with the brake power ($\dot{W}_b$).

$$bsfc = \dot{m}_f / \dot{W}_b \quad (2.5)$$

2.9 GT-POWER

GT-Power which is a short form for Gamma Technologies Power software is an industry-standard engine simulation that is widely used among engine and vehicle makers, their suppliers, ship and power-generation engines, either small 2 or 4 stroke engines and also racing cars such as F1,NASCAR, and also IRL. GT-Power also one of the components in GT-Suite which is there are about five others components in it. They are GT-Drive, GT-Vrain, GT-Fuel, GT-Cool and GT-Crank. Each one of them has their own purpose.

As for GT-Power, it has a capability to simulate the engine's performance and also acoustic analysis with control capabilities. It provides many components to model any advanced concept. Because of its ease of use and also its tight integration with the rest of GT-Suite, where as giving GT-Power a virtual engine perspective. The environment of GT-Suite also provides GT-Power with a proven set of high-productivity features for pre- and post-processing, DOE or optimization, neural networks and also transient simulations. It also can be used for analysis of engine or power train control. It can either be a standalone tool coupled with GT-Drive, GT-Fuel and GT-Cool as the GT-Suite flow product.

GT-Power applications included torque curve and fuel consumption. Besides that, we can also do the manifold design and tuning. Transient performance and response also can be determined by using this software. Another application are valve profile and timing optimization, combustion and emissions, turbocharger response and matching, EGR system design, acoustic analysis which is intake or exhaust noise, full system warm-up, control system analysis, real-time engine modelling, design analysis by combining user with DOE and lastly coupled 1D with 3D simulations.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Basically a four stroke engine cycle will undergo four operations starting with intake stroke where the inlet valve is opened and the fuel and air mixture is drawn in as the piston travels down. Then compression stroke take place making inlet valve closed and piston travels back up the cylinder compressing the fuel and air mixture. Just before piston reaches the top of its compression stroke a spark plug emits a spark to combust the fuel and air mixture.

As for diesel engine a glow plug will ignite the mixture inside the chamber and combustion will occur. The number of degrees before the top its stroke is the ignition advance. When the piston is at the top of its travel it is at top dead centre (TDC). Combustion stroke will continued after compression stroke. The piston is forced down by the pressure wave of the combustion of the fuel air mixture and gives power to the engine. After combustion stroke, exhaust stroke take place. The exhaust valve is opened and the piston travels back up expelling the exhaust gases through the exhaust valve. At the top of this stroke the exhaust valve is closed. This process is then repeated.

3.2 LITERATURE STUDY

Starting the simulation required enough study from literature review. The study will improves understanding of the project and gives general idea of the project. Literature review will be a boundary for the simulation to take place part from the scopes. Main key from literature review is, addition of hydrogen in diesel engine combustion will increases engine performance and can be the future alternative fuel. Thus, the four main engine performance parameters will be the focus of this simulation;

i. brake efficiency
ii. volumetric efficiency
iii. bmep
iv. bsfc

3.3 MODELLING THE 1D DIESEL ENGINE

The crucial part for simulation to run is setting up the diesel engine model. The engine is where required result can be obtained after the simulation is run. Hence, the engine specification use for this simulation is shown in Table 3.1. The air intake pressure is defined as 1bar since the condition can be assumed at atmosphere pressure while the temperature of intake is defined as 300K.

Table 3.1: Engine specification

Description	Specification
Displacement	785.4cc
Bore	100mm
Stroke	100mm
Number of cylinder	1
Connecting rod length	200mm
Compression ratio	16.5
Piston pin offset	1

Basically the engine specification is given by the software as a default mode. Since the consideration is only to obtained the engine performance when hydrogen combustion with diesel fuel is applied, hence using the default mode as the engine specification will not affect the entire scopes of study.

3.3.1 Starting the simulation

Engine simulation can be run after the main 1D engine is set-up. The simulation begins with only diesel fuel burn with air in combustion, and then the speed is increase by increment of 500rpm starting with 1000rpm until 3500rpm. In this study, basic theory to add hydrogen gas into the fuel is by mixing hydrogen gas with air. In the simulation mass fraction of air should be equal to one.

Ergo, some simple calculation is required to mix hydrogen gas with air. As show in APPENDIX C, before altering oxygen and nitrogen gas in air composition the initial value is 0.233% and 0.767% respectively which giving the total mass fraction of 1% of air.

Hydrogen mass fraction use in this study is 0.005%, 0.0075% and 0.010% present in air. To add hydrogen into air, firstly hydrogen mass fraction must be divided to two as shown in equation (3.1);

$$\frac{m_{H2}}{2} \tag{3.1}$$

where;

m_{H_2} ; hydrogen mass fraction

After that, oxygen and nitrogen mass fraction must be deduct with half value of hydrogen mass fraction as shown in equation (3.2) and (3.3);

$$m_{O_2} - \frac{m_{H2}}{2} = X_{O_2} \tag{3.2}$$

where;

m_{O_2} ; oxygen mass fraction

X_{O_2} ; new mass fraction of oxygen

$$m_{N_2} - \frac{m_{H2}}{2} = Y_{N_2} \tag{3.3}$$

where;

m_{N_2} ; nitrogen mass fraction

Y_{N_2} ; new mass fraction of nitrogen

Hence, when the new value of oxygen mass fraction and nitrogen mass fraction is added with value of hydrogen mass fraction the total value is equal to one as shown in equation (3.4);

$$m_{H_2} + X_{O_2} + Y_{N_2} = 1 \tag{3.4}$$

The total mass fraction must be equal to one percent so that the simulation can be run. If the mass fraction do not equal to one percent, no result can obtained. Then, study of hydrogen will undergo the same method as diesel fuel where various speed will be applied to see whether engine speed will bring any significant to performance. Values obtained after calculation is made for the simulation is shown in Table 4.1.

3.4 ANALYSIS OF SIMULATION RESULT

After the simulation finished with diesel and diesel-hydrogen combustion, data are obtained. However, the data have to validate with hypothesis made for this study. If the data obtained is contradicted with hypothesis made, it will be discussed further in chapter five. This study may focus on four main engine performance characteristic, however other result also obtained to justify the effect of hydrogen addition during combustion. Other results obtained are:

i. rate of pressure rise
ii. pressure in cylinder
iii. temperature in cylinder
iv. heat transfer rate
v. rate heat release
vi. p-v diagram

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

The result is presented by graph to show four performance parameters of the engine simulation are affected by the addition of hydrogen mass fraction in the air. Hydrogen mass fraction tested in the simulation is 0.005%, 0.0075 and 0.010%.

4.2 HYDROGEN MASS FRACTION

Table 4.1 shows the mass fraction of air after hydrogen is added into it. Basically for combustion there are two main components in air that contribute to burning fuel. Fuel cannot be burn only with oxygen but also with nitrogen present in the combustion.

As show in table above n2-vap, o2-vap and h2-vap is defined as nitrogen, oxygen and hydrogen vapour respectively within the GT-Suite program. It can be seen that without hydrogen present in the air, the mass fraction must be equal to one. Hence, when hydrogen mass fraction is added into the air, nitrogen and oxygen will decrease in value of its mass fraction.

For each mass fraction of hydrogen added into the air will be divided into two and the value will be deduct from nitrogen and oxygen. Thus, the total mass fraction will be equal to one. If total mass fraction not equal to one, the program will not run and no result will be produce.

Table 4.1: Hydrogen mass fraction

n2-vap,%	o2-vap,%	h2-vap,%
0.767000	0.233000	0.00000
0.764500	0.230500	0.00500
0.763250	0.229250	0.00750
0.762000	0.228000	0.01000

4.3 RESULT

The result show in where four performance parameters are obtained by addition of hydrogen mass fraction into air. Then the result is plotted in figure so it can be compared.

Table 4.2: bmep with three hydrogen mass fraction

Speed (rpm)	bmep (bar)			
	Diesel	0.0050% Hydrogen	0.0075% Hydrogen	0.0100% Hydrogen
1000	7.7956	4.7118	3.3327	2.0146
1500	8.6256	5.4942	4.0225	2.4381
2000	8.9708	5.8022	4.3078	2.4015
2500	9.2448	5.9286	4.3619	2.2184
3000	9.4589	6.0879	4.4448	2.0032
3500	9.4598	6.1279	4.4465	2.4338

Table 4.3: Brake efficiency with three hydrogen mass fraction

Speed (rpm)	Brake efficiency (%)			
	Diesel	0.0050% Hydrogen	0.0075% Hydrogen	0.0100% Hydrogen
1000	17.7984	10.2355	7.1024	4.2238
1500	19.6934	11.9140	8.5512	5.4860
2000	20.4816	12.5696	9.1452	5.9862
2500	21.1071	12.8316	9.2504	6.0433
3000	21.5960	13.1578	9.4108	6.1417
3500	21.5980	13.2263	9.3977	6.0862

Table 4.4: bsfc with three hydrogen mass fraction

Speed (rpm)	bsfc (g/kWh)			
	Diesel	0.0050% Hydrogen	0.0075% Hydrogen	0.0100% Hydrogen
1000	470.3850	806.7090	1156.5600	1936.3000
1500	425.1210	692.7210	959.9690	1489.5800
2000	408.7610	656.4190	897.2840	1364.4900
2500	396.6470	642.855	886.8370	1351.1800
3000	387.6690	626.677	871.3370	1328.9400
3500	387.6330	623.2020	872.1360	1340.3400

Table 4.5: Volumetric efficiency with hydrogen mass fraction

Speed (rpm)	Volumetric efficiency (%)			
	Diesel	0.0050% Hydrogen	0.0075% Hydrogen	0.0100% Hydrogen
1000	74.9547	72.8379	71.8439	70.8664
1500	77.5743	75.5068	74.5272	73.5691
2000	79.0823	76.9640	76.0001	75.0776
2500	81.2473	78.3342	77.1213	76.0382
3000	83.8545	80.4743	78.9155	77.5274
3500	85.7466	82.5199	80.8529	79.3051

Table 4.6: Maximum rate of pressure rise with hydrogen mass fraction

Speed (rpm)	Maximum rate of pressure rise (bar/degree)			
	Diesel	0.0050% Hydrogen	0.0075% Hydrogen	0.0100% Hydrogen
1000	2.3084	2.6408	2.6747	2.6757
1500	2.5200	2.6308	2.6794	2.4381
2000	2.4200	2.4168	2.3817	2.4015
2500	2.2716	2.4060	2.4085	2.2184
3000	1.8690	2.0834	2.0956	2.0032
3500	1.7942	2.0229	2.0400	2.4338

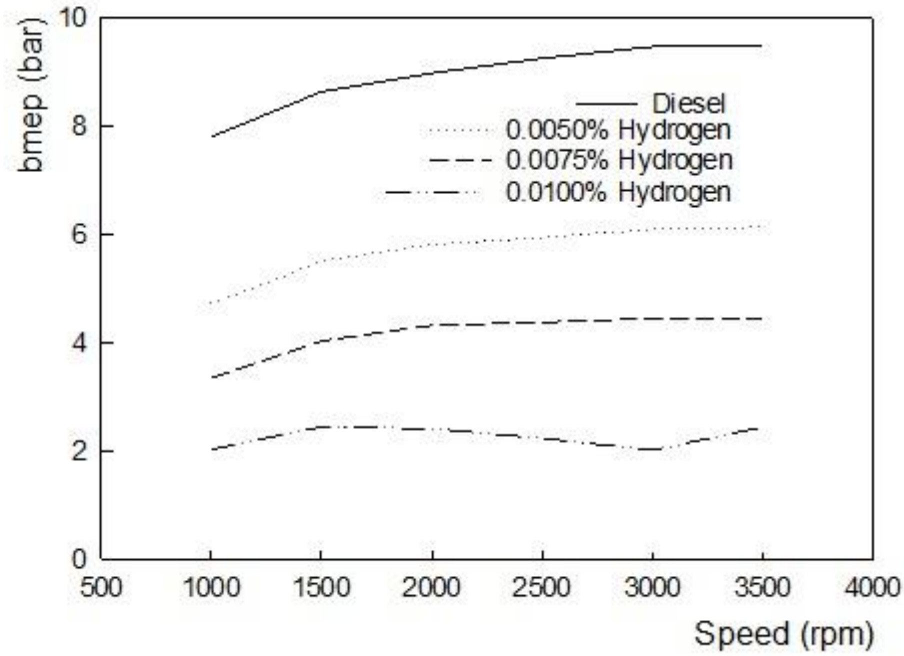

Figure 4.1: Brake mean effective pressure against speed

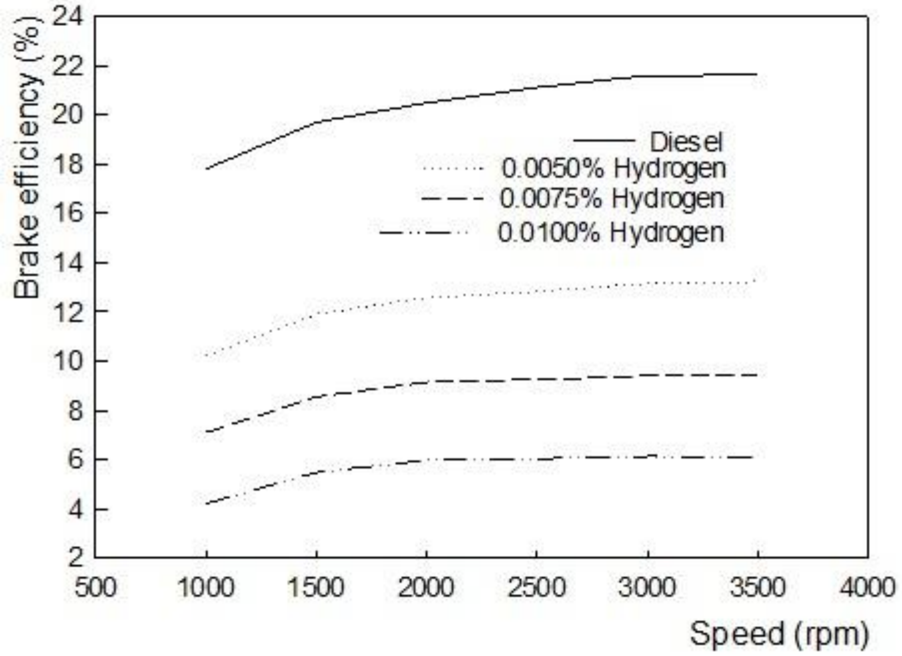

Figure 4.2: Brake efficiency pressure against speed

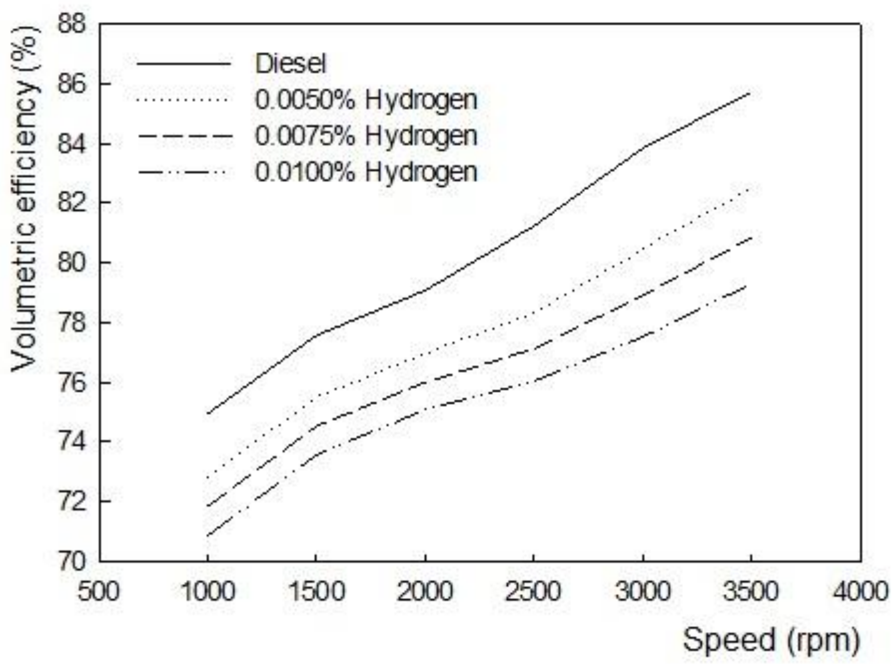

Figure 4.3: Volumetric efficiency consumption against speed

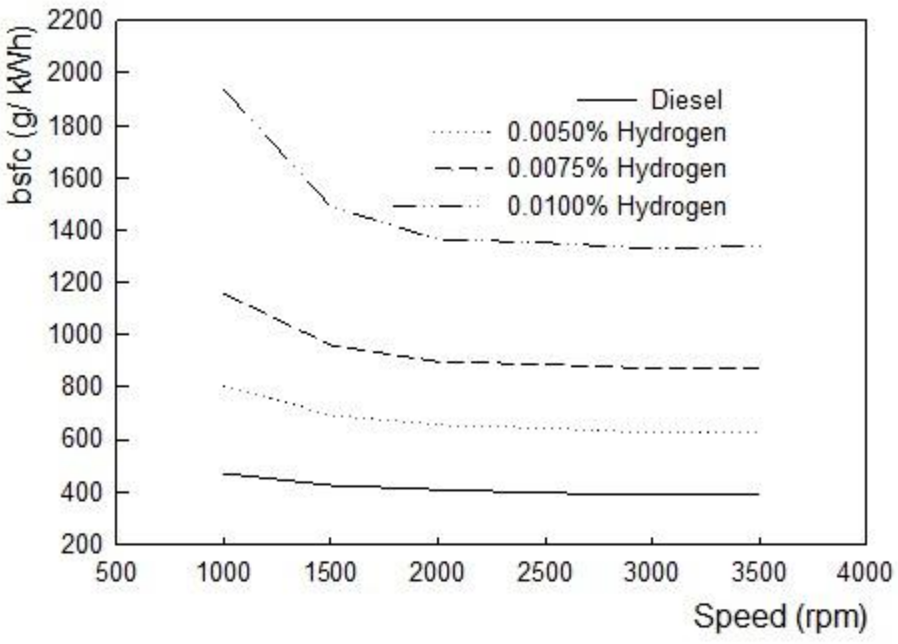

Figure 4.4: Brake specific fuel consumption against speed

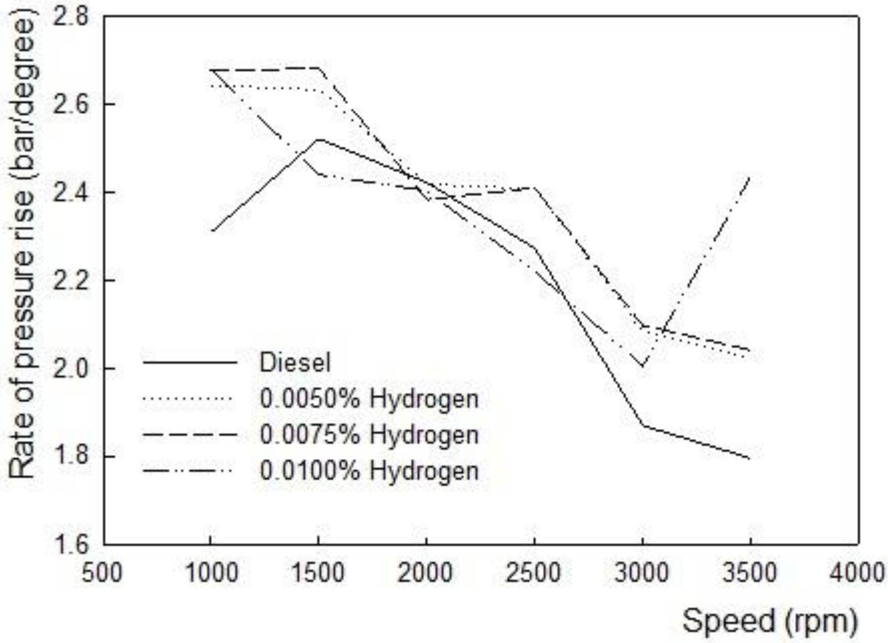

Figure 4.5: Rate of pressure rise against speed

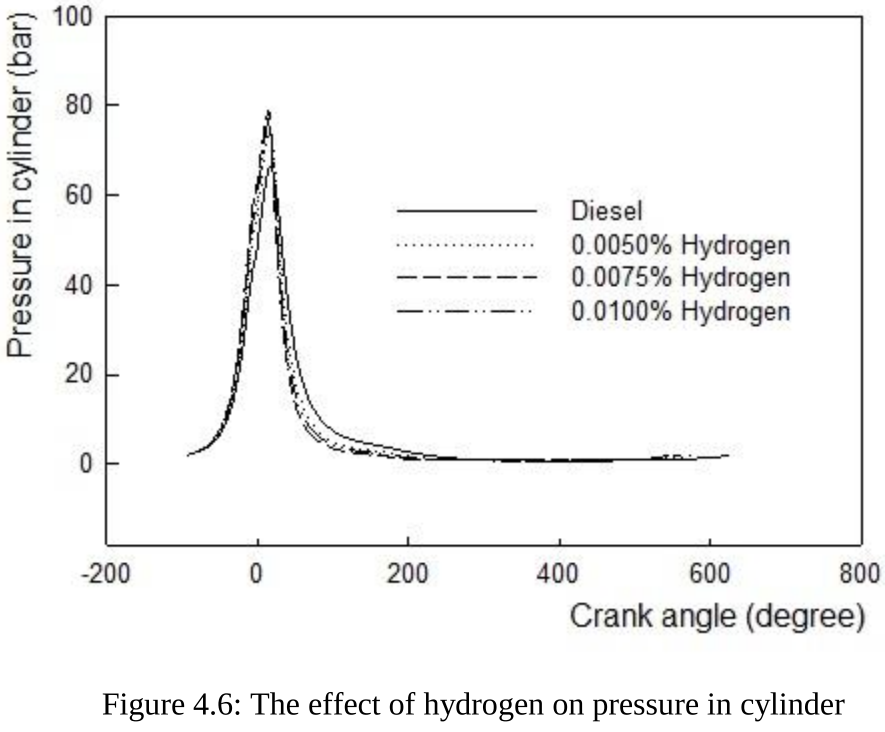

Figure 4.6: The effect of hydrogen on pressure in cylinder

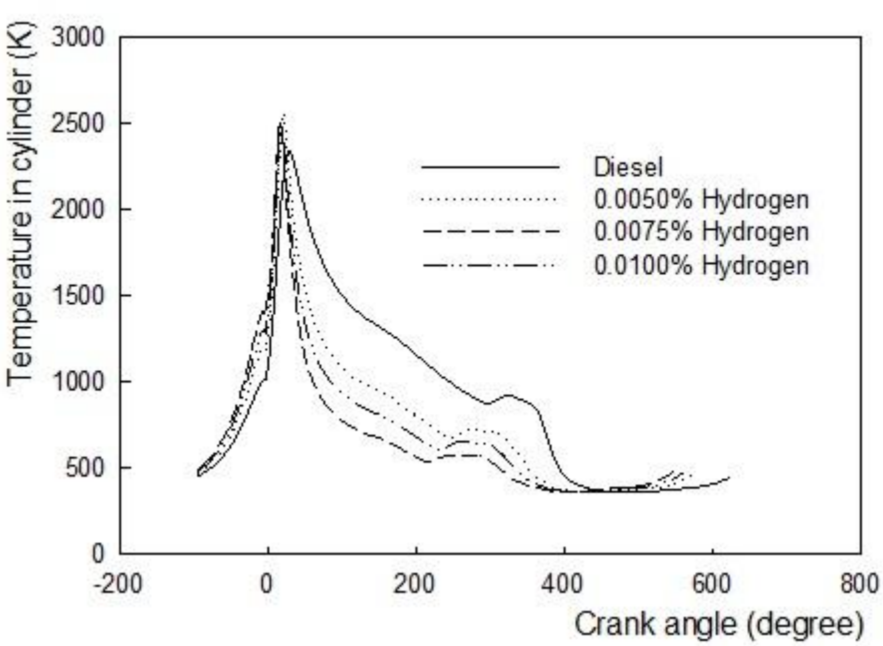

Figure 4.7: The effect of hydrogen on temperature in cylinder

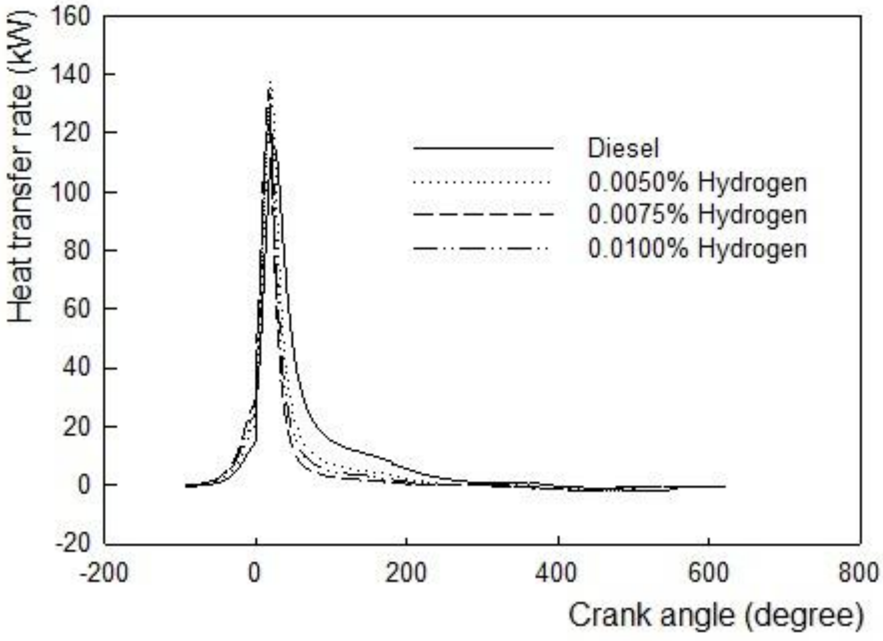

Figure 4.8: The effect of hydrogen on heat transfer rate

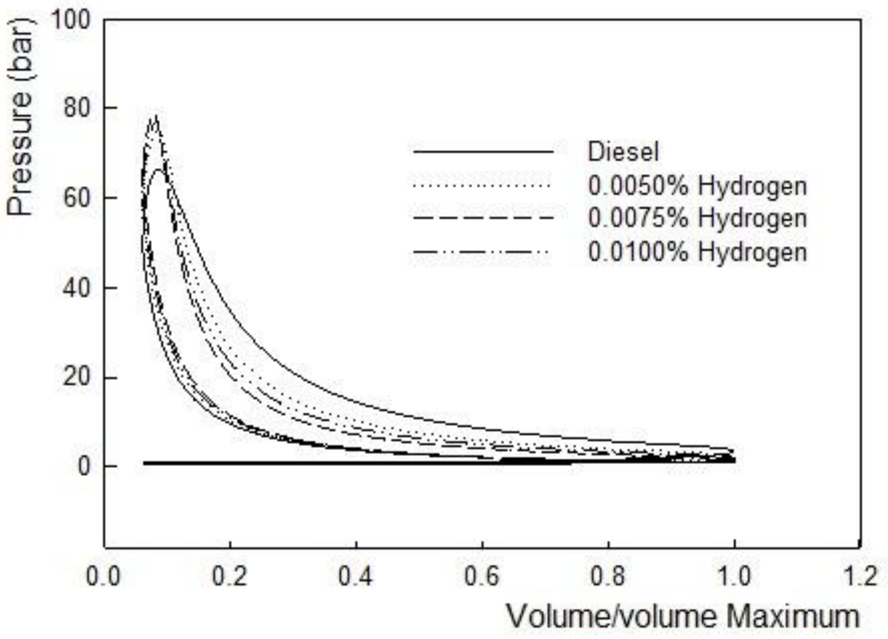

Figure 4.9: The effect of hydrogen on P-v diagram

4.4 DISCUSSION

Figure 4.1 shows bmep against hydrogen mass fraction. It can be seen that bmep is decreasing with increasing of speed and it occur for three hydrogen mass fraction 0.0050%, 0.0075% and 0.0100%. Without addition of hydrogen in intake air, the maximum bmep obtained is 9.4598 bar at speed 3500 rpm and with addition of 0.0050%, 0.0075% and 0.0100% hydrogen mass fraction the bmep is 6.1279 bar, 4.4465 bar and 2.9311 bar respectively at 3500 rpm.

Why more hydrogen mass fraction in air result with low bmep is because due to separation of air molecule at high temperature following combustion, molecular oxygen present in burned gases under stoichiometric condition. Thus other fuel molecule will be burned. This effect increases the pressure and result in increase mean effective pressure. But with more hydrogen is added air molecule is depleting more precisely oxygen molecule. Hence, temperature will decrease slightly during combustion and effect mean effective pressure.

Figure 4.2 indicates the brake efficiency versus hydrogen mass fraction. From the graph, it can be seen that brake efficiency is dropping drastically with addition of hydrogen mass fraction. For non-addition of hydrogen, the brake efficiency is 21.5980% with maximum speed 3500 rpm. When 0.0050% hydrogen mass fraction added into the air, brake efficiency is 13.2263% with maximum speed 3500 rpm. For 0.0075% hydrogen mass fraction brake efficiency is 9.4000% with maximum speed 3500rpm while 0.01% of hydrogen mass fraction, the brake efficiency obtained is 6.0862% with maximum speed 3500rpm.

Figure 4.2 shows that with higher speed brake efficiency are lower compared to low speed. This is because at higher speed more friction losses. Friction losses contribute on decreasing in brake efficiency. In the other hand, adding hydrogen for combustion decreases brake efficiency due to depleting of temperature in the chamber, the same effect that cause bmep to decrease.

Figure 4.3 shows the volumetric efficiency versus hydrogen mass fraction. It can be seen that the volumetric efficiency is decreasing with increasing hydrogen mass fraction. Without any mass fraction of hydrogen is added into the air, volumetric efficiency is 85.7466% with maximum speed 3500rpm. For 0.005% mass fraction of hydrogen addition volumetric efficiency is 82.5199%, volumetric efficiency obtained for 0.0075% mass fraction of hydrogen is 80.8529%, while volumetric efficiency for 0.0100% hydrogen mass fraction is 79.3051%.

Figure 4.3 shows with higher speed the volumetric efficiency decrease slightly compared with low speed. In general, the high speed gives high vacuum at the intake port and consequent larger air flow rate that goes inside the cylinder. The importance of volumetric efficiency is more critical for hydrogen engines because of the hydrogen fuel displaces large amount of the incoming air due to its low density (0.0824kg m^{-3} at 25°C and 1atm).

This reduces the volumetric efficiency to high extent. The stoichiometric mixture of hydrogen and air consists of approximately 30% hydrogen by volume, whereas a stoichiometric mixture of fully vaporized diesel and air consists of approximately 1% diesel by volume. Therefore, the low volumetric efficiency for hydrogen adding is expected compared with diesel engine works with the same operating conditions and physical dimension.

Finally when 0.01% hydrogen mass fraction of hydrogen added into air, the volumetric efficiency is 79.3051% with maximum speed 3500rpm. Figure 4.4 indicates the bsfc against hydrogen mass fraction. From the graph, it can be observe that bsfc is increasing with increase of hydrogen mass fraction. Base on the result, without the present of hydrogen mass fraction in air bsfc obtained is 387.6330g/kWh with maximum speed 3500rpm. When 0.005% hydrogen mass fraction is added into air the bsfc is 623.2020g/kWh with maximum speed 3500rpm.

For 0.01% hydrogen mass fraction added in air fraction the bsfc is 1340.3400g/kWh with maximum speed 3500rpm. Figure 4.4 shows that at higher speed bsfc are greater than lower speed. In general, higher speed contributes to more air intake hence more fuel need to be burn. Why bsfc is increasing with increasing hydrogen mass fraction due to lack of oxygen present in the mixture. More diesel fuel is needed to supply the energy.

Figure 4.5 indicate the rate of pressure rise with different speed tested. The highest pressure rate by using only diesel in combustion is 2.52bar/degree with speed 1500rpm. Mean while the highest pressure rate achieve with 0.0050% addition of hydrogen is 2.6408bar/degree with speed 1000 rpm while for 0.0075% mass fraction the highest value obtained is 2.6794 bar/degree at 1500rpm. With addition of 0.0100% hydrogen in air mass fraction, the highest value obtained is 2.6757bar/degree with speed 1000rpm.

4.5 UNCERTAINTIES IN RESULT

Base from the discussion, all performance parameters give a negative effect after hydrogen mass fraction is added into air. However, result base on pressure and temperature increase in cylinder shows a positive result. The simulation will generate two types of result. One of them will generate graph result base on selection what result we want to observe. The other result only gives numerical result and should be plotted manual. In this experiment, the data is plotted using Sigma Plot software.

Detail explanation on Figure 4.6, the pressure curve has the tendency to shift to the right as hydrogen is added into the cylinder charge since hydrogen with high auto-ignition temperature (858K) ignites after ignition of diesel. The sudden increase in pressure with the addition of hydrogen in combustion indicates auto-ignition of hydrogen has been reached parallel to ignition of diesel. This is due to high flame speed of hydrogen (3.24 to 4.40m/s) causes fast combustion propagation of the in-cylinder charge which was only initiated from diesel ignition.

Plus, the higher peak pressure because of higher heating value (142MJ/kg) and diffusivity (0.6cm^2/s) of hydrogen. The high diffusivity facilitates the formation of a uniform mixture of hydrogen with other cylinder charge since this contributes greatly to ensure an equal supply of hydrogen to all regions in the cylinder.

Additionally, wide range flammability of hydrogen promotes complete combustion of hydrogen throughout the cylinder even within the lean mixture regions. With very lean cylinder charge the bulk of the energy release comes from the ignition and subsequent rapid combustion of the small diesel zone (R. Adnan, 2010). It comes also from the combustion of diesel fuel and from the immediate surroundings of such zone where higher temperature and relatively richer mixture regions are present (Liu, 2008).

The moment all the mixture ignites simultaneously, the heat release is much stronger resulting in higher temperature gradient as shown in Figure 4.6 plus the increase in pressure also contribute to high peak temperature. However, do to limitation of the tool use it can be recognized that combustion of diesel-hydrogen do not undergo lean mixture between diesel fuel and air. This is because the mass fraction of air had been reduce due addition of mass fraction of hydrogen in air mixture.

In Figure 4.8 indicate the heat transfer rate of diesel and diesel-hydrogen combustion. It can be seen that the curve is slightly shift to the left where hydrogen is added into the combustion. The same factor that effect pressure curve, hydrogen has higher auto ignition temperature (858K) and it will ignite after hydrogen. The reason hydrogen addition in combustion result in higher pick heat release is due to its higher heating value (141.80MJ/kg) compared to diesel (44.80MJ/kg). Heating value or energy value is the amount of heat released during combustion of specified amount of it. The energy value is a characteristic for a substance. When diesel is combust, it releases the internal energy in it. Combustion of diesel trigger hydrogen to combust, then hydrogen releases a higher internal energy after combustion.

These also explain why in Figure 4.8, the heat transfer rate is higher with hydrogen addition into combustion. Higher internal energy release from hydrogen is spread through cylinder wall, and some of this heat is transfer to the piston, cylinder wall and valve. The combustion of hydrogen releases a great heat that it is absorb by convection and radiation process that undergo after combustion. Plus the only heat transfer consider in this study is convection and radiation.

Figure 4.9 shows the increase in pressure from P-v diagram should not occur with hydrogen mass fraction addition in air base on early discussion. In addition, hydrogen present in combustion increases the power output as shown in the P-v diagram. Comparing the area below line from P-v diagram indicates that addition of hydrogen contribute on more space as observed from hydrogen addition P-v diagram where as integration of the area result in work.

More work equal to more power produced. The higher engine power with hydrogen addition is due to the additional heat released from hydrogen combustion and the reduced combustion duration (Mihaylov Milen, 2004). The combustion of hydrogen addition provides additional heat energy, which is one of the reasons for higher engine output.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The objective of this study is to determine the effects of hydrogen mixing with diesel fuel in engine combustion. A 1D diesel engine was use to determine its four basic performance by using software to run 1D engine simulation. Before any strict decision is made of hydrogen effect in this study, the hypothesis must be justified first. The hypothesis made is hydrogen will give a positive result on engine performance. However after undergo this study; the result gives negative effect on engine performance. Performance parameters that are considered in this study are bmep, brake efficiency, volumetric efficiency and bsfc.

Brake efficiency, bmep, and volumetric efficiency results in decreases of value while bsfc shown an increased value. This negative result continues when more hydrogen is added into the combustion. Very low density of hydrogen displaced air volume in hydrogen and air mixture. Contribute in low volumetric efficiency. Low volumetric efficiency results in low combustion pressure with low combustion temperature. Hence bmep will decrease as well. In a nut shell, base on the simulation result adding hydrogen in diesel combustion does not contribute in increase of engine performance. However, hydrogen only helps the reduction of NO_x emission with other hazardous emission. This is due to reduction in temperature in combustion chamber where as reducing NO_x formation after combustion. Result in less air pollution by low emission.

5.2 RECOMMENDATION

Studies of engine performance by adding hydrogen into engine combustion and considering it as a fuel source, has to extend with a higher degree of study. Nevertheless, hydrogen as fuel is much better considering on emission problem faced right now. Even though hydrogen give negative effects on engine performance, due to strict legislation in Europe fuel source that contribute in low emission is highly needed this. Hence, with the decreases in fossil fuel source another fuel alternative like hydrogen can be considered.

Plus the limitation face while running the simulation is that the air intake is reduce due to additional of hydrogen mass fraction. 1D simulation done by using GT-Power software is not quit suitable if there are two fuels involved during combustion. This can be considered as an error while running this simulation, in addition higher knowledge to use this tool is also essential.

REFERENCES

BOYLE G, EVERETT B & RAMAGE J. (2003) Energy systems and sustainability, First edition, Oxford, Oxford university press.

Biplab K. Debnath, Ujjwal K. Saha and Niranjan Sahoo. Effect of hydrogen-diesel quantity variation on brake thermal efficiency of a dual fuelled diesel engine. Journal of Power Technologies 92 (1) (2012) 55–67

C. Liew, H. Li, J. Nuszkowski, S. Liu, T. Gatts, R. Atkinson and N. Clark. An experimental investigation of the combustion process of a heavy-duty diesel engine enriched with H2. International journal of hydrogen energy 35 (2010) 11357 e11365

Gregory K. Lilik, Hedan Zhang, Jose´ Martin Herreros, Daniel G. Haworth and Andre´ L. Boehman. Hydrogen assisted diesel combustion. International Journal of Hydrogen Energy 35 (2010) 4382-4398.

Haroun A.K. Shahad and Nabeel Abdul-Hadi. Experimental Investigation of the Effect of Hydrogen Manifold Injection on the Performance of Compression Ignition Engines. World Academy of Science, Engineering and Technology 76 2011

HOFFMANN P. (2002) Tomorrow's energy - Hydrogen, Fuel cells abd the prospects for a cleaner planet, First edition, Cambridge, Massachussets, MIT. International journal of Mechanical and Materials Engineering (IJMME), Vol.5 (2010), No.2, 136-141

K. S. VARDE and G. A. FRAME. HYDROGEN ASPIRATION IN A DIRECT INJECTION TYPE DIESEL ENGINE-ITS EFFECTS ON SMOKE AND OTHER ENGINE PERFORMANCE PARAMETERS. International Association for Hydrogen Energy (1983)

KRASAE-IN S, STANG J H & NEKSA P. (2010) 'Development of large-scale hydrogen liquefaction processes from 1898 to 2009', International Journal of Hydrogen Energy, Vol. 35, issue 10, May 2010, pp 4524-4533

Liu X, Liu F. and Schock H.J. 2008. Backfire prediction in manifold injection hydrogen internal combustion engine, Hydrogen, Energy, 33, 3847-3855

LEMUS RG & MARTÍNEZ DUART JM. (2010) 'Updated hydrogen production costs and parities for conventional and renewable technologies', International Journal of Hydrogen Energy, Vol. 35, issue 9, May 2010, pp 3929-3936

M. Masood and M.M. Ishrat. Computer simulation of hydrogen-diesel dual fuel exhaust gas emissions with experimental verification. Fuel 87 (2008) 1372-1378

Murari Mohon Roy, Eiji Tomita, Nobuyuki Kawahara, Yuji Harada and Atsushi Sakane. An experimental investigation on engine performance andemissions of a supercharged H2-diesel dual-fuel engine. international journal of hydrogen energy 35
(2010) 844–853

Mihaylov Milen and Barzev Kiril. (2004) Investigation of the effects of hydrogen addition on performance and exhaust emissions of diesel engine. FISITA WORLD AUTOMOTIVE CONGRESS, BARCELONA 2004.

M.M. Rahman, Mohammed K. Mohammed and Rosli A. Bakar. Effect of Air Fuel Ratio on Engine Performance of Single Cylinder Port Injection Hydrogen Fueled Engine: A Numerical Study. Proceedings of the International MultiConference of Engineers and Computer Scientist 2009 Vol II IMECS 2009, March 18-20, 2009

M. Masood, M.M. Ishrat and A.S. Reddy. Computational combustion and emission analysis of hydrogen-diesel blends with experimental verification. International Journal of Hydrogen Energy 32 (2007) 2539-2547

N. Saravanan, G. Nagarajan, G. Sanjay, C. Dhanasekaran, K.M. Kalaiselvan. Combustion analysis on a DI diesel engine with hydrogen in dual fuel mode. Fuel 87 (2008) 3591-3599

N. Saravanan, G. Nagarajan, K.M. Kalaiselvan, C. Dhanasekaran. An experimental investigation on hydrogen as a dual fuel for diesel engine system with exhaust gas recirculation technique. Renewable Energy 33 (2008) 422–427

N. Saravanan, G. Nagarajan, K.M. Kalaiselvan, C. Dhanasekaran. An experimental investigation on hydrogen as a dual fuel for diesel engine system with exhaust gas recirculation technique. Renewable Energy 33 (2008) 422–427

N. Saravanan, G. Nagarajan and S. Narayanasamy. An experimental investigation on DI diesel engine with hydrogen fuel. Renewable Energy 33 (2008) 415–421

N. Saravanan and G. Nagarajan. An experimental investigation of hydrogen-enriched air induction in a diesel engine system. International Journal of Hydrogen Energy 33 (2008) 1769-1775

Probir Kumar Bose and Dines Maji. An experimental investigation on engine performance and emissions of a single cylinder diesel engine using hydrogen as inducted fuel and diesel as injected fuel with exhaust gas recirculation. International journal of hydrogen energy 34 (2009) 4847–4854

R. Adnan, H.H. Masjuki, and T.M.I Mahlia. Experiemntal investigation on in-cylinder pressure and emissions of diesel engine with port injection hydrogen system.

VERHELST S & WALLNER T. (2009) 'Hydrogen-fueled internal combustion engines', Progress in Energy and Combustion Science, Vol. 35, issue 6, 18th September 2009, pp 490-527

APPENDIX A

GANTT CHART FOR FYP 1

Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Receive title and buy log book from FKM															
Literature study															
Introduction															
Study on recent hydrogen research															
Start chapter two															
Methodology flow chart															
Start chapter three															
Presentation preparation															
Presentation for FYP 1															

APPENDIX B

GANTT CHART FOR FYP 2

Project activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Preparing for simulation																
Result verification																
Discussion																
Conclusion and recommendation																
Preaentation for FYP 2																
Final report preparation																

APPENDIX C

AIR COMPOSITION MASS FRACTION

Attri...	Basic Fluid Object	Mass Fraction
Unit		
1	n2-vap	0.767
2	o2-vap	0.233
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

SCHEMATIC DIAGRAM