# SPRAY SIMULATION OF HYDROGEN FUEL FOR SPARK IGNITION ENGINE USING COMPUTATIONAL FLUID DYNAMIC (CFD)

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BACHELOR OF ENGINEERING

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# UNIVERSITI MALAYSIA PAHANG

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**SESI PENGAJIAN: 2010/2011**

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# SPRAY SIMULATION OF HYDROGEN FUEL FOR SPARK IGNITION ENGINE USING COMPUTATIONAL FLUID DYNAMICS (CFD)

ABDUL RAHMAN BIN MOHD SABRI

Report submitted in partial fulfill the requirement for the awards of Bachelor of Mechanical Engineering with Automotive Engineering

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DECEMBER 2010

## SUPERVISOR'S DECLARATION

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

Signature:
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**STUDENT'S DECLARATION**

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

Signature:
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| | |
|---|---|
| κ-ε | k-epsilon |
| λ | fuel air ratio |
| μ | micro |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| 2D | Two dimensional |
| 3D | Three dimensional |
| ATDC | After top dead center |
| BTDC | Before top dead center |
| ABDC | After bottom dead center |
| BBDC | Before bottom dead center |
| CA | Crank angle |
| CFD | Computational Fluid Dynamics |
| CFM | Coherent flame model |
| $CO_2$ | Carbon dioxide |
| DI | Direct injection |
| FC | Fuel cell |
| ICE | Internal combustion engine |
| H2FC | Hydrogen fuel cell |
| H2ICE | Hydrogen internal combustion engine |
| HEV | Hybrid electric vehicle |
| HHV | High heating value |
| K | Kelvin |
| LHV | Low heating value |
| NTP | Normal temperature and pressure |
| NOx | Nitrogen oxides |
| SI | Spark Ignition |
| TDC | Top dead center |

## ABSTRACT

This thesis deals with the numerical study about the simulation of hydrogen fuel in spark ignition engine during the event of compression and combustion process using Computational Fluid Dynamics (CFD). The selection of the combustion model is vital in order to fulfil three major criteria which are accuracy and computational cost. Current study utilised the finite rate/ eddy-dissipation model to simulate the hydrogen fuel combustion and single step reaction mechanism of stoichiometric hydrogen-air mixture is simulated. Turbulence is captured using k-ε-realizable model. Yamaha FZ150i engine has been chosen as the baseline engine design. The simulated engine condition is 2000 rpm while the hydrogen injection pressure is set as 6 bar for a $15^o$ CA of injection period. This project simulates the compression and combustion process between 300 CA until 400 CA. The assessment is based on cylinder pressure inside the engine model. The predicted maximum pressure due to hydrogen combustion is 62 bar while maximum temperature is 2687 K. 0.00759 of hydrogen mass fraction is burned during $7^o$ CA of hydrogen combustion period. The pressure data for pressure in engine model is validated using previous experimental data. However, there are discrepancies of the result due to improper boundary condition and inherit limitation of model. For further simulation of combustion process, more data from experimental work is needed such as pressure, temperature and injection data to implement in the simulation.

## ABSTRAK

Tesis ini berkaitan dengan kajian berangka tentang simulasi bahan bakar hidrogen dalam percikan motor bakar selama proses mampatan dan proses pembakaran dengan menggunakan Computational Fluid Dynamic (CFD). Pemilihan model pembakaran sangat penting dalam rangka memenuhi tiga kriteria utama iaitu ketepatan, kos, dan masa pengkomputeran. Kajian yang terbaru menggunakan tahap terhad / eddy disipasi model untuk mensimulasikan pembakaran bahan bakar hidrogen dan langkah mekanisme reaksi tunggal dari campuran stoikiometri hidrogen-udara disimulasikan. Aliran gelora dikaji dengan menggunakan model k-ε-realisasi. Enjin Yamaha FZ150i telah dipilih sebagai reka bentuk asas model enjin. Keadaan operasi enjin yang disimulasikan adalah pada 2000 rpm sedangkan tekanan injeksi hidrogen ditetapkan sebagai 6 bar untuk putaran sebanyak 15 sudut tempoh suntikannya. Projek ini mensimulasikan proses mampatan dan pembakaran antara sudut putaran 300 hingga 400. Penilaian ini dikaji berdasarkan pada tekanan silinder dalam model enjin. Tekanan maksimum dianggarkan akibat pembakaran hidrogen adalah 62 bar, sedangkan suhu maksimum adalah 2687 K. 0,00759 nisbah jisim hidrogen dibakar selama tempoh 7 sudut putaran pembakaran hidrogen. Data Tekanan untuk tekanan dalam model mesin dibandingkan dengan menggunakan data simulasi yang dahulu. Namun, ada perbezaan pada keputusan akibat nilai yang tidak tepat dan mewarisi keterbatasan model. Untuk kajian proses pembakaran masa hadapan, data yang lebih banyak daripada hasil eksperimental diperlukan seperti tekanan, suhu dan data suntikan untuk digunakan dalam simulasi.

# CHAPTER 1

# INTRODUCTION

## 1.1 PROJECT BACKGROUND

Alternative fuels usually clean fuels compared to diesel and gasoline in the engine combustion process. Compared with other kind of fuels, hydrogen has the following advantages. Its resources are vast and it can be generated through several ways. Extensive studies were performed on hydrogen fueled internal combustion engines (White, 2006). It is particularly suitable for fuelling internal combustion engines (Yusuf, 2005). The flow field identification inside a cylinder of internal combustion engines during intake, compression, expansion and exhaust strokes are an important stage for comprehension of physical phenomenon which occurs in the motor cycle.

The movement of the inlet air fuel mixture has a great influence on the performance of the engine. Developments in the engine simulation technology have made the virtual engine model a realistic suggestion (Li, 2000). Nowadays, computational fluid dynamics codes are used to simulate the engine performance and visualize the flow characteristics (Bahram, 1994). Application of these codes for engine improvement have saved significant time and cost in the design and development stage of combustion engine system. (Shojaeefard and Noorpoor, 2008).

Throughout this thesis, the simulation of hydrogen fuel for spark ignition engine using computational fluid dynamics is be developed. The importance regarding this project is to predict the variation of combustion pressure inside the engine cylinder.

## 1.2 PROBLEM STATEMENT

There are some problems regarding hydrogen utilisation for internal combustion engine as fuel. Hydrogen produces a clean combustion. One of the primary problems encountered in the development of operational hydrogen engines is premature ignition (pre-ignition). Pre-ignition occurs when the cylinder charge becomes ignited before the ignition by the spark plug. If this condition occurs when the intake valve is open, the flame can travel back into the induction system. Moreover, the difference of injection strategy will produce the different power output from the hydrogen combustion.

## 1.3 OBJECTIVES

Based on the problem statement above, this project is conduct to achieve the following objectives:

1. To simulate the direct injection combustion process using hydrogen fuel.
2. To predict the variation of combustion pressure inside the engine cylinder.

## 1.4 SCOPES

The scopes of this project are:

1. To calculate pressure of hydrogen combustion using CFD approach during both valves closed.
2. Develop the engine structure in 2D geometry model based on Yamaha FZ150i engine dimension.
3. Grid generation and boundary condition setup.
4. Simulation of cold flow and combustion process using hydrogen
5. Validate CFD approach by compare the pressure data with previous simulation data.

## 1.5 ORGANIZATION OF THESIS

This thesis consists of five main chapter, introduction, literature review, methodology, result and discussion and the last part is conclusion and recommendation. In Chapter 1 presents some findings that lead to problems statement, objectives, scopes and flow chart of work. Chapter 2 is literatures review that related to the study and as a study framework. In chapter 3, presents the dimensioning work on Yamaha FZ150i engine model, development of 2D model and mesh generation. Then, Chapter 4, address the validation of predicted results against previous simulation results of the cylinder pressure. Last but not least, Chapter 5 presents the important findings of the study and recommendation for further study.

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